DAHLGREN DIVISION
NAVAL SURFACE WARFARE CENTER
Dahlgren, Virginia 22448-5100

NSWCDD/TR-00/009

IMPROVEMENTS IN PITCH DAMPING FOR THE AEROPREDICTION CODE WITH PARTICULAR EMPHASIS ON FLARE CONFIGURATIONS

BY FRANK G. MOORE TOM C. HYMER

WEAPONS SYSTEMS DEPARTMENT

APRIL 2000

Approved for public release; distribution is unlimited.

20000323 123

DTIC QUALITY INSPECTED 3

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, search existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services. Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 2000	Final

4. TITLE AND SUBTITLE

Improvements in Pitch Damping for the Aeroprediction Code with Particular Emphasis on Flare Configurations

5. FUNDING NUMBERS

6. AUTHOR(s)

Frank G. Moore, Tom C. Hymer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Commander
Naval Surface Warfare Center
Dahlgren Division (Code G04)
17320 Dahlgren Road
Dahlgren, VA 22448-5100

8. PERFORMING ORGANIZATION REPORT NUMBER

NSWCDD/TR-00/009

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

New capability has been added to the NSWC aeroprediction code to allow aerodynamics to be predicted for Mach numbers up to 20 for configurations with flares. This new capability includes extending the static aerodynamic predictions for Mach numbers less than 1.2, improving the body alone pitch damping for Mach numbers above 2.0, and developing a new capability for pitch damping of flared configurations at Mach numbers up to 20.

This new capability for flared configurations was validated for several different configurations in the Mach number range of 2 to 8.8. In general, pitch damping predictions of the improved capability was within 20 percent of either experimental data or computational fluid dynamics calculations. This accuracy level is believed to be quite adequate for dynamic derivatives in the preliminary design stage. These new additions to the aeroprediction code will be transitioned to users as part of the 2002 version of the code (AP02).

14. SUBJECT TERMS

aerodynamics, Aeroprediction Code, Mach number, flares, pitch damping

15. NUMBER OF PAGES

51

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORTS	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI std. Z39-18
298-102

FOREWORD

The 1998 version of the aeroprediction code (AP98) used an empirical method to compute pitch damping of bodies alone. This method was based on a 1970's version of a model developed by Bob Whyte of General Electric (GE) (Bob has since left GE and formed his own company). The method was a data base that used aerodynamics of Army and Navy spin stabilized shells as a means to estimate aerodynamics of other configurations. The Whyte code (referred to as the "GE Spinner" code) worked well for configurations that had Mach numbers less than about 3.0. However, for many missile configurations at high Mach numbers, or configurations that used flares for stability, the GE Spinner code gives erroneous answers, since it was not developed with those conditions in mind. The work presented in this report develops new semiempirical technology to address the weak areas of the GE Spinner code for the pitch damping coefficient.

The work described in this report was supported through the Office of Naval Research through the Surface Weapons Systems Technology Program managed at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) by Mr. Robin Staton. Tasking from this program was provided by Mr. Roger Horman and Mr. John Fraysse. Also, some support was provided by the Ballistic Missile Defense Program through Mr. George Long. The authors express appreciation for support received in this work.

Approved by:

JOHNNY WALTERS, Deputy Head
Weapons Systems Department

CONTENTS

ILLUSTRATIONS

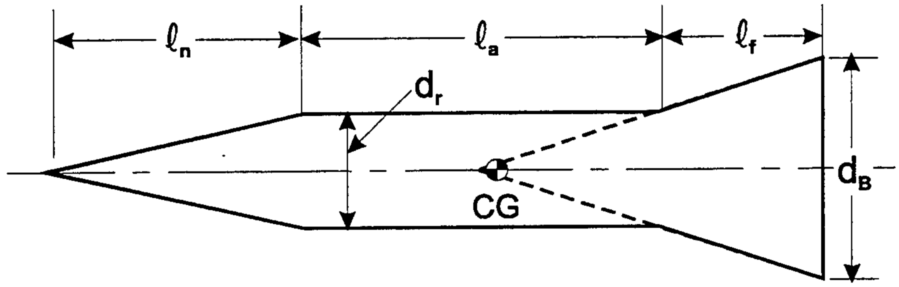
ILLUSTRATIONS (Continued)

1.0 INTRODUCTION

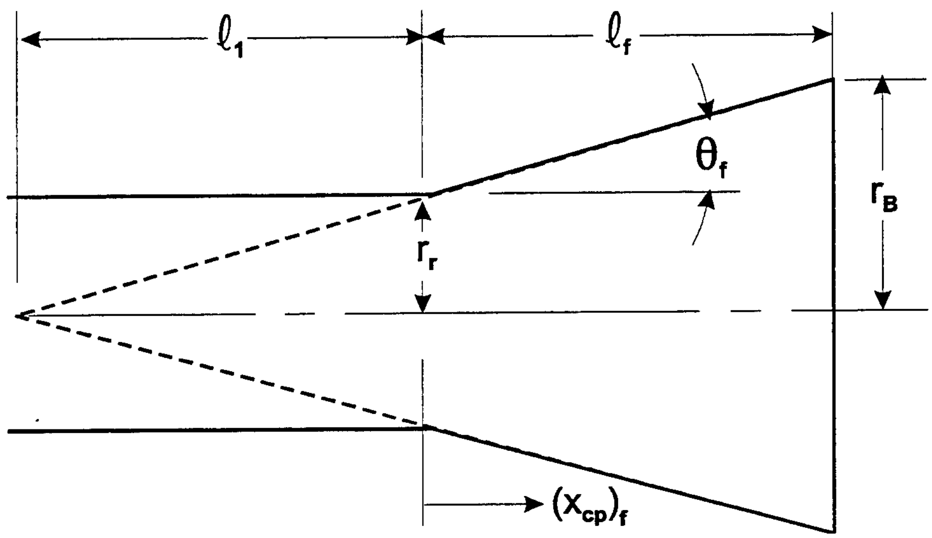
The 1998 version of the NSWCDD Aeroprediction Code (AP98)[1] is the most complete and comprehensive semiempirical code produced to date. It includes the capability to predict planar aerodynamics in the roll positions of $\Phi = 0$ deg (fins in "+" or plus orientation as viewed from the rear of the missile) and $\Phi = 45$ deg (fins in "×" or cross roll orientation as viewed from the rear of the missile) over a broad range of flight conditions and configuration geometries with good average accuracy, computational times and ease of use. Flight conditions include angles of attack (AOA) up to 90 deg, control deflections of up to ±30 deg, and Mach numbers up to 20. Configuration geometries include axisymmetric and nonaxisymmetric body shapes with sharp, blunt, or truncated nose tips, with or without a boattail or flare. Up to two sets of planar or cruciform fins are allowed. New technology has recently been developed[2] to allow both six- and eight-fin options in the fin considerations as well. Also, many of the constants used in the aeroprediction code have been refined[3] based on a more recent wind tunnel data base,[4] allowing more accurate aerodynamic estimates at angle of attack. Average accuracies are ±10 percent for normal and axial force and ±4 percent of body length for center of pressure. Average accuracy means that enough AOAs or Mach numbers are considered to get a good statistical sample. On occasion a single data point can exceed these average accuracy values. Ease of use has been significantly enhanced over older versions of the Aeroprediction Code (APC) through a personal-computer-based pre- and post-processor package.[5] This package has allowed inputs for configuration geometries to be simplified significantly by many automated nose shape options.

While the AP98 is a very powerful tool, several limitations and areas of improvement still remain. Most of these needs are driven by the desire of future weapon designers to perform trade studies on new and innovative concepts that may fall outside of the current capability of the AP98. An example of this type of requirement is the multi-fin requirement that has just been completed.[2] Another example of this type of requirement is to include the capability to deflect the rear segment of a fin (sometimes referred to as flaperon or aileron) for control, as opposed to the entire fin. Also, the capability to predict drag accurately for all power on conditions is desired. Finally, improvement in aerodynamics of projectiles that use a flare for stability (as opposed to fins) is needed. This report will deal with the last problem area of improving aerodynamics of configurations that use a flare for stability. Figure 1 illustrates the typical geometrical parameters associated with a flare. The two most important parameters are the flare length and angle, which can also be expressed in terms of the flare base to forward or reference diameter.

The problem of inaccurate aerodynamic predictions for flared configurations from the APC first came to the author's attention a couple of years ago in the form of the pitch damping moment coefficient predictions for a flared projectile concept at a AIAA meeting. The increased interest in the use of flares for stability in recent years, particularly for higher Mach numbers (see



A. Cone-Cylinder-Flare Configuration



B. Expanded View of Flare

FIGURE 1. TYPICAL FLARE CONFIGURATION WITH THE SIGNIFICANT GEOMETRICAL PARAMETERS

References 6-8 for example), has also led the author to feel that improvements in the aerodynamic predictions of flared projectiles were needed.

As a result of the increased interest in flared projectiles for higher Mach number applications, the author decided to take a relook at the APC to determine its weak areas with respect to flared shaped projectiles. Several problem areas were identified. First of all, for the static aerodynamics, no particular attention was given for flared projectiles for $M_\infty < 1.2$. For $M_\infty \geq 1.2$, low AOA aerodynamics are computed by theoretical methods such as Second-Order-Van-Dyke (SOVD) or Second-Order-Shock-Expansion-Theory (SOSET) and reasonable estimates of static aerodynamics (C_A, C_N, x_{CP}) can be obtained from the APC. For $M_\infty < 1.2$, the capability to compute static aerodynamics needs to be incorporated into the code.

The second problem uncovered in the APC prediction of aerodynamics was for the dynamic derivative, $C_{M_q} + C_{M_{\dot{\alpha}}}$, or pitch damping moment coefficient. No capability exists at any Mach number in the APC for pitch damping moment of flared projectile shapes. In fact,

based on recent computational fluid dynamic (CFD) calculations of projectiles without a flare,[9,10] it was found that the pitch damping moment of configurations without flares needed improvement as well. Table 1 summarizes the problems in predicting aerodynamics of flared projectile shapes.

TABLE 1. AP98 WEAK AREAS IN PREDICTING AERODYNAMICS OF FLARED CONFIGURATIONS

a) C_A, C_N, x_{CP} not available for $M_\infty < 1.2$ for flare
b) Body alone $C_{M_q} + C_{M_{\dot{\alpha}}}$ needs improvement for $M_\infty \geq 1.2$ (no flare)
c) No pitch damping contribution for flare in AP98 at any M_∞

2.0 ANALYSIS

Each of the three weak areas mentioned in the Introduction and listed in Table 1 will be discussed individually in this section of the report. The discussion will be in terms of modifications that will be made to the AP98 to allow more accurate computations of aerodynamics of flared projectiles. These modifications will then be a part of the next release of the APC which will be the AP02 in 2002.

2.1 STATIC AERODYNAMICS OF FLARED PROJECTILES

The wave component of axial force for configurations with small flare angles ($\theta_f < 15$ deg) can be calculated approximately with the perturbation theory of Wu and Aoyoma[11] that was designed for boattails, except the angle is reversed in sign. There was a sign error in the AP98, but when this error was corrected, approximate estimates of wave drag for $M_\infty < 1.2$ could be computed from the Reference 11 method. For $M_\infty < 0.9$, the wave drag component is assumed to be zero. Base drag and skin-friction drag were already being computed within the accuracy desired using the AP98 so no changes in the methodology for these aerodynamic terms were made.

The normal force and pitching moment coefficients and center of pressure for the flares are not predicted at all for $M_\infty < 1.2$. Furthermore, numerical methods do not exist in the AP98 to allow calculations of C_N, C_M and x_{CP} for $M_\infty < 1.2$. Also, as will be discussed later in the pitch damping computations for flares, C_N, C_M and x_{CP} for a flare will be needed at all Mach numbers.

To compute $\left(C_{N_\alpha}\right)_f$ and $(x_{CP})_f$, one of several options are available. The first is to utilize the available values in the APC. Unfortunately, these values are only available for $M_\infty \geq 1.2$ where pressures are computed and integrated over the body surface. Also, the logic of the APC is such that this would require considerable changes to allow these calculations to be performed

and brought forward into another subroutine. The second option would be to exercise the APC twice, once with a flare and once without and subtract the C_{N_α}'s and C_{M_α}'s to obtain the flare normal force coefficient derivative and its center of pressure. Again, this is not a very desirable alternative since the APC must be exercised twice to get a single number. A third option, which appears more attractive, is to exercise the APC code offline, compute values of $\left(C_{N_\alpha}\right)_f$ and $(x_{CP})_f$ for $M_\infty \geq 1.2$ and store these in a table lookup as a function of geometric and freestream parameters. For $M_\infty < 1.2$, slender body theory (SBT) can be used to approximate values of $\left(C_{N_\alpha}\right)_f$ and $(x_{CP})_f$. The fourth and most attractive option is to use available cone tables[12] or approximate conical formulas to compute $\left(C_{N_\alpha}\right)_f$, use SBT to approximate the center of pressure of the flare and $\left(C_{N_\alpha}\right)_f$ for $M_\infty < 1.2$, and to include these parameters in a table lookup as a function of geometry and Mach number. This last option can be used since we are assuming the flare is a conical frustrum or can be approximated by a conical frustrum. The last option is the one that will be used in this analysis as it has the advantage of being at least as accurate as current computations in the APC due to use of an exact cone solution from Reference 12. Also, this approach offers the opportunity to obtain results in a straightforward and direct way from the APC as opposed to more costly approaches of logic change in the APC or cycling through the APC twice to obtain results for the flare alone.

The C_{N_α} results for the total cone of Reference 11 must be corrected to include only the frustrum portion of the cone and also put in the appropriate reference area format. Referring to Figure 1, the percent of conical shape that is a flare is:

$$\frac{A_f}{A_C} = \frac{\pi\left[r_B^2 - r_r^2\right]}{\pi r_B^2} = 1 - \left(\frac{r_r}{r_B}\right)^2 \tag{1}$$

Now the value of C_{N_α} obtained from Reference 12 is based on the cone base area. Hence, Equation (1) must be multiplied by A_B/A_r to place it in the same reference area as other C_{N_α} components for the total configuration of Figure 1. Thus, to relate the value of the C_{N_α} from Reference 12 for a cone of given angle at a given Mach number to that of a flare we have

$$\left(C_{N_\alpha}\right)_f = \left(C_{N_\alpha}\right)_C \left[1 - \left(\frac{r_r}{r_B}\right)^2\right]\left(\frac{r_B}{r_r}\right)^2$$

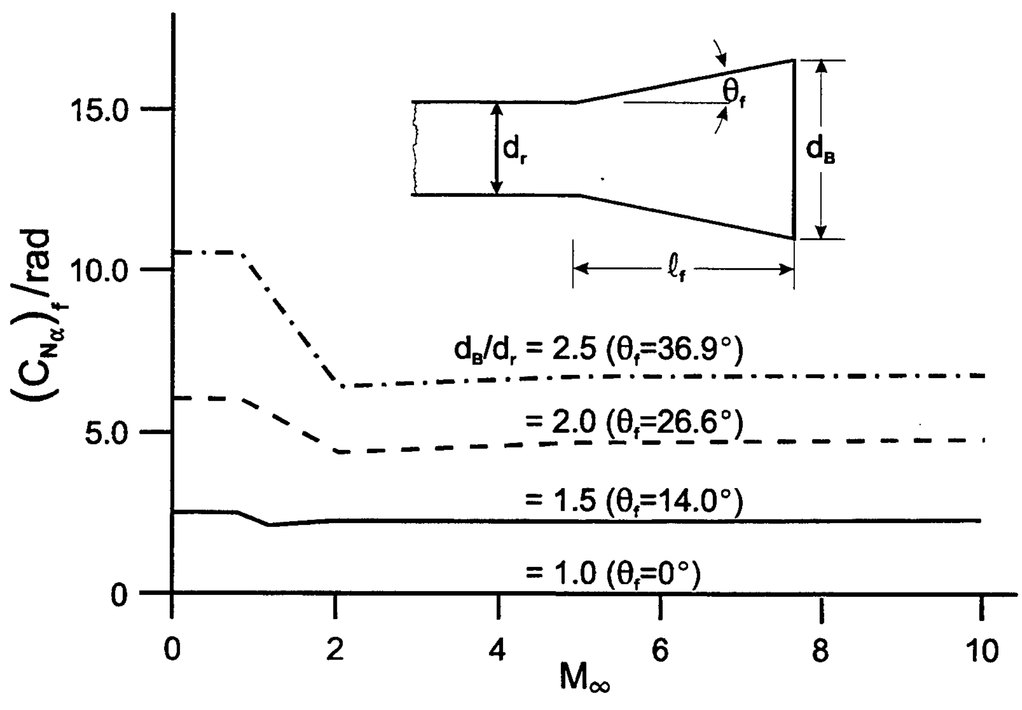
or

$$\left(C_{N_\alpha}\right)_f = \left(C_{N_\alpha}\right)_C \left[\left(\frac{r_B}{r_r}\right)^2 - 1\right] \tag{2}$$

Equation (2) is valid at all Mach numbers and for all geometries. However, $(C_{N_\alpha})_C$ is available from Reference 12 for conditions where the flow is supersonic and the shock wave is attached to the conical tip. For conditions where these two assumptions are not met, SBT will be assumed in conjunction with interpolation. SBT gives

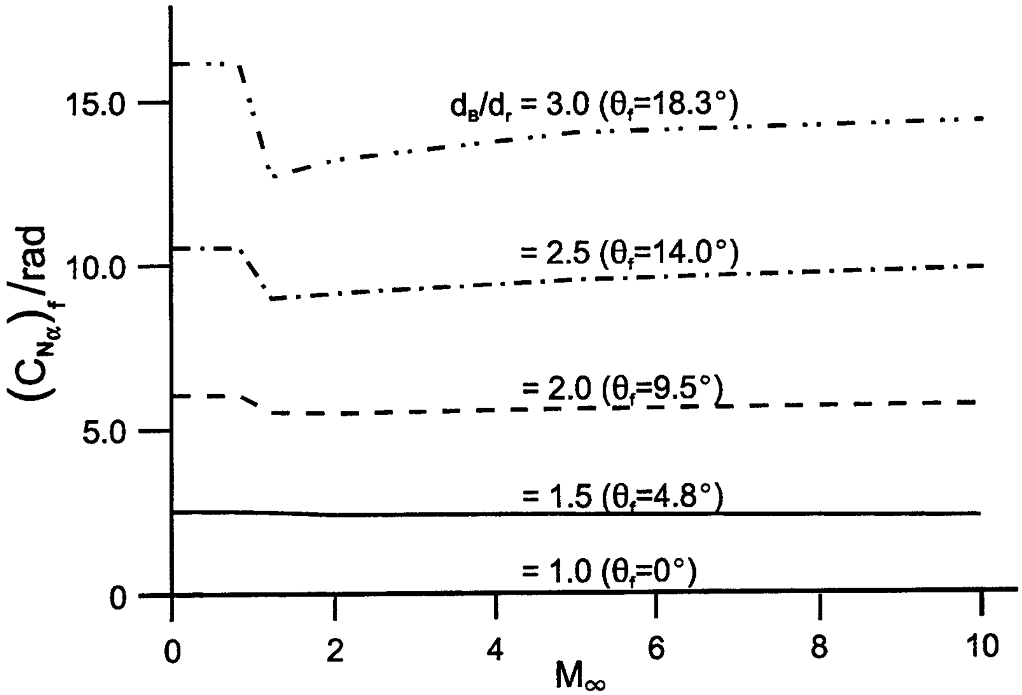
$$(C_{N_\alpha})_C = 2.0 \tag{3}$$

This value of $(C_{N_\alpha})_C$ will be assumed for $M_\infty \leq 0.8$. The value of $(C_{N_\alpha})_C$ from Reference 12 can be used for low AOA calculations of most reasonable flares down to M_∞ of about 1.2. Linear interpolation between SBT and Reference 12 will be used for $0.8 < M_\infty$ 1.2. Figure 2 gives results of Equations (2) and (3) as a function of Mach number and the parameter d_B/d_r. Again, $(C_{N_\alpha})_C$ of Equation (2) and Figure 2 is based on Reference 12 supersonically, Equation (3) subsonically, and linear interpolation of these two methods transonically.

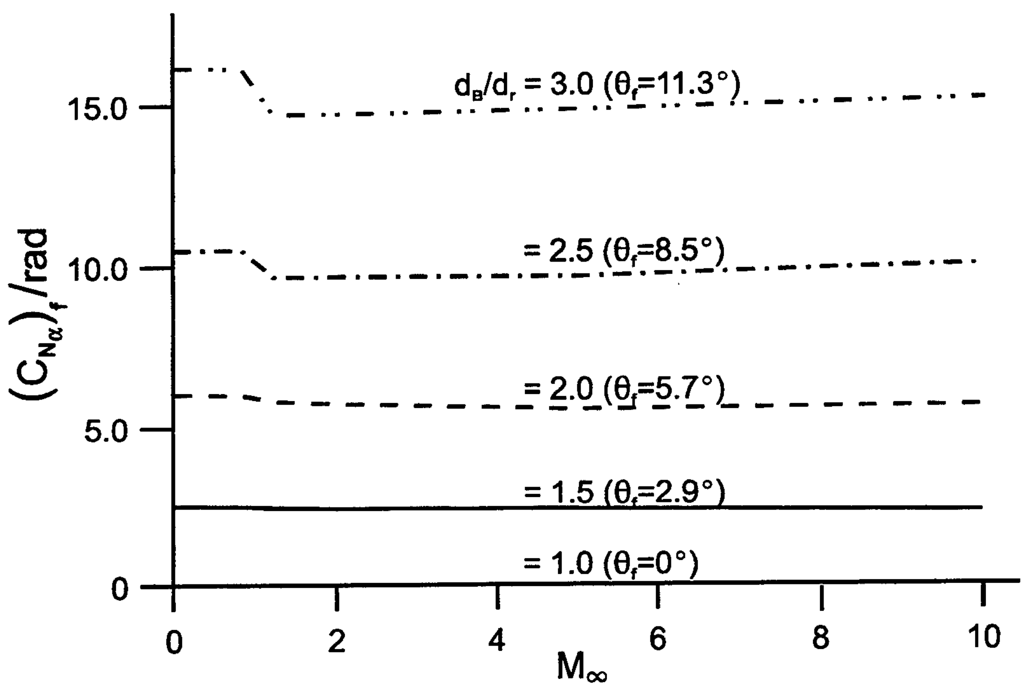


A. $\ell_f/d_r = 1.0$

FIGURE 2. NORMAL FORCE COEFFICIENT DERIVATIVE OF FLARES BASED ON SBT AND NASA TR 1135[12]



B. $\ell_f/d_r = 3.0$



C. $\ell_f/d_r = 5.0$

FIGURE 2. NORMAL FORCE COEFFICIENT DERIVATIVE OF FLARES BASED ON SBT AND NASA TR 1135[12] (CONT.)

In examining Figure 2, it is seen that the C_{N_α} for a flare can get quite large if the flare is long or if the flare is short but has a large flare angle. This is why use of a flare is quite popular at higher Mach numbers, where the C_{N_α} for a fin decreases substantially with Mach number increase.

The SBT center of pressure for a cone is the same as that from exact theory. The center of pressure is at 2/3 of the cone length. However, for a conical frustrum, the center of pressure in general will vary between 0.5 ℓ_f and 2/3 ℓ_f, depending on the flare angle. For flare angles approaching 0, the value of $(x_{CP})_f$ approaches 0.5 ℓ_f whereas for large flare angles, $(x_{CP})_f$ approaches 2/3 ℓ_f. Referring to Figure 1, the center of pressure of the flare can be calculated from

$$\overline{x}_{CP} = \frac{x_{CP}}{\ell_1 + \ell_f} = \frac{\int_{\ell_{1/(\ell_1+\ell_f)}}^{1} \overline{x} A'(\overline{x}) d\overline{x}}{\int_{\ell_{1/(\ell_1+\ell_f)}}^{1} A'(x) dx} \tag{4}$$

where $A(x) = \pi \overline{r}^2 (\overline{x}); \overline{r} = r/(\ell_1 + \ell_f)$

Also,

$$A'(x) = 2\pi \overline{r}\, \overline{r}' = 2\pi \overline{x} \tan^2 \theta_f \tag{5}$$

Substituting Equation (5) into Equation (4), integrating and carrying out the algebra, one obtains:

$$\overline{x}_{CP} = \frac{2}{3} \frac{\left[1 - (\ell_1/(\ell_1 + \ell_f))^3\right]}{\left[1 - (\ell_1/(\ell_1 + \ell_f))^2\right]} \tag{6}$$

but since $\frac{\ell_1}{\ell_1 + \ell_f} = \frac{r_r}{r_B}$,

Equation (6) can be written in a more convenient form as

$$\overline{x}_{CP} = \frac{2}{3} \frac{\left[1 - (r_r/r_B)^3\right]}{\left[1 - (r_r/r_B)^2\right]} \tag{7}$$

Equation (7) can also be written in a more useful form in terms of x_{CP}/ℓ_f versus $x_{CP}/(\ell_1 + \ell_f)$ which is Equation (7). In terms of x_{CP}/ℓ_f, one can write

$$\frac{x_{CP}}{\ell_f}=\frac{2}{3}\left(\frac{1}{1-r_r/r_B}\right)\left[\frac{1-(r_r/r_B)^3}{1-(r_r/r_B)^2}\right] \tag{8}$$

One can also shift the point where x_{CP} is measured from the cone tip to the point where the flare begins by a simple translation where

$$(\bar{x}_{CP})_f=\frac{(x_{CP})_f}{\ell_f}=\frac{x_{CP}-\ell_1}{\ell_f}$$

or

$$(\bar{x}_{CP})_f=\frac{2}{3}\left(\frac{1}{1-r_r/r_B}\right)\left[\frac{1-(r_r/r_B)^3}{1-(r_r/r_B)^2}\right]-\frac{r_r/r_B}{1-r_r/r_B} \tag{9}$$

Results of Equation (9) are computed and plotted in Figure 3 as a function solely of the parameter r_r/r_B. As seen in the figure, when the body consists of a cone ($r_r = 0$), then the center of pressure is at 2/3 of the cone or flare length (which are one and the same). On the other hand, when the flare angle goes to zero so that $r_r/r_B = 1.0$, the center of pressure goes to $x_{CP}/\ell_f = 0.5$. For most typical flare lengths and angles, x_{CP}/ℓ_f will vary from about 0.54 to 0.60.

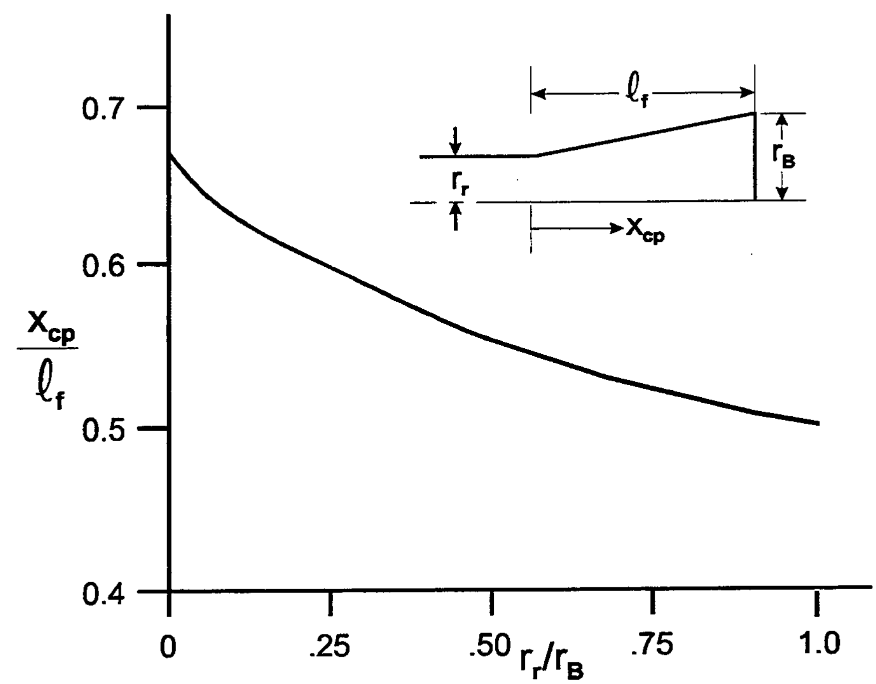


FIGURE 3. SLENDER BODY THEORY CENTER OF PRESSURE OF FLARE

Equation (9) results can be changed to body diameters by multiplying Equation (9) by ℓ_f/d to obtain:

$$\left(\frac{x_{CP}}{\ell_f}\right)\left(\frac{\ell_f}{d}\right)=\frac{(x_{CP})_f}{d} \tag{10}$$

The combination of Figures 2 and 3 give the C_{N_α} and x_{CP} for flares at all Mach numbers. C_N is simply

$$C_{N_f}=\left(C_{N_\alpha}\right)_f \alpha \tag{11}$$

for small angles of attack. Since most flare configurations are designed to fly at small angles of attack, Figures 2 and 3 and Equations (10) and (11) determine two of the desired static aerodynamic terms for a flare. The pitching moment coefficient of the flare about some reference location is then

$$C_M=-\left(\frac{x_{CP}-x_{CG}}{d}\right)C_{N_f} \tag{12}$$

2.2 BODY ALONE PITCH DAMPING MOMENT

The body alone dynamic derivatives are all computed based on an empirical model developed by Whyte,[13] called "Spinner." The version that is incorporated into the AP98 is basically the same version as initially included in the APC series in 1977. The technology of Reference 13 was based on curve fits of data using standard spin stabilized rounds. The curve fits have key parameters of length, boattail length, and Mach number for the dynamic derivative predictions. Magnus force and moments are also estimated at both 1 and 5 deg angles of attack to incorporate some nonlinearity due to AOA in the Magnus moment. The data bases upon which the empirical curve fits were based were primarily limited to about 5.5 calibers and Mach numbers less than 5.0 (newer versions of Spinner may now be available which remove these limits). However, length was considered in a linear sense for roll damping moment and one of the data bases had length as a parameter for pitch damping moments as well.

Since the late 1960's and early 1970's, the Army Research Laboratory (ARL) at Aberdeen, Maryland has developed a very good CFD capability to compute both static and dynamic derivatives of projectiles, with and without flares. References 6, 7, 9, and 10 are some of the reports generated by ARL using CFD. As a result of these many CFD computations, and comparison to data, one can now fine tune the older "Spinner" Model[13] to be more representative of a broader class of configurations.

In comparing the AP98 (in essence the "Spinner" model) predictions of pitch damping moment to ballistic range data and CFD predictions of References 6, 7, 9, and 10, a problem existed. The Spinner results appeared to be reasonable for $M_\infty \leq 1.2$ but overpredicted

$C_{M_q} + C_{M_{\dot{\alpha}}}$ as Mach number increased. The higher the Mach number, the worse the predictions became. On the other hand, the errors followed a fairly smooth pattern, allowing a correction to be derived based on CFD results from References 6, 7, 9, and 10.

The modified pitch damping moment coefficient for bodies without a flare present is therefore

$$C_{M_q} + C_{M_{\dot{\alpha}}} = \left(C_{M_q} + C_{M_{\dot{\alpha}}}\right)_S F_1 \tag{13}$$

where $\left(C_{M_q} + C_{M_{\dot{\alpha}}}\right)_S$ is the value obtained from the AP98[1] which basically uses Reference 13. F_1 is an empirical decay factor for Mach number derived using the AP98 and References 6, 9, and 10. Here, F_1 is a function of Mach number and total length of the projectile and is defined by the following model.

a) $\underline{\ell/d \leq 5.0}$

$$\begin{aligned} F_1 &= 1.0 && ; \; M_\infty \leq 1.2 \\ F_1 &= 0.0043\, M_\infty^2 - 0.151\, M_\infty + 1.175 && ; \; 1.2 < M_\infty \leq 5.0 \\ F_1 &= 0.53 && ; \; M_\infty > 5.0 \end{aligned} \tag{14}$$

b) $\underline{\ell/d = 8}$

$$\begin{aligned} F_1 &= 1.0 && ; \; M_\infty \leq 2.0 \\ F_1 &= 0.0031\, M_\infty^2 - 0.0884\, M + 1.164 && ; \; 2.0 < M_\infty \leq 5.0 \\ F_1 &= 0.8 && ; \; M_\infty > 5.0 \end{aligned} \tag{15}$$

c) $\underline{5 < \ell/d < 8}$

$$F_1 = F_1\,(\ell/d=5) - \left(\frac{\ell/d-5}{3}\right)\left[F_1\,(\ell/d=5) - F_1\,(\ell/d=8)\right] \tag{16}$$

d) $\underline{\ell/d \geq 12}$

$$\begin{aligned} F_1 &= 1.0 && ; \; M_\infty \leq 2.0 \\ F_1 &= 0.0011\, M_\infty^2 - 0.111\, M_\infty + 1.178 && ; \; 2 < M_\infty \leq 5.0 \\ F_1 &= 0.9 && ; \; M_\infty > 5.0 \end{aligned} \tag{17}$$

e) $\underline{8 < \ell/d < 12}$

$$F_1 = F_1\,(\ell/d=8) - \left(\frac{\ell/d-8}{4}\right)\left[F_1\,(\ell/d=8) - F_1\,(\ell/d=12)\right] \tag{18}$$

2.3 PITCH DAMPING MOMENT OF BODIES WITH FLARES

A typical body configuration with a flare present is shown in Figure 1. As already mentioned, the AP98 code does not calculate a value of additional pitch damping due to the presence of a flare. The approximate method used here to represent the flare is basically to use the Reference 14 approach where

$$\left(C_{M_q} + C_{M_{\dot{\alpha}}}\right)_f = -2\left(C_{N_\alpha}\right)_f \left(\frac{x_{CP} - x_{CG}}{d}\right)_f^2 \tag{19}$$

Equation (19) was used in Reference 14 to approximate the pitch damping moment coefficient of a wing, but here the flare replaces the wing planform area. $\left(C_{N_\alpha}\right)_f$ of Equation (19) is defined by Equations (2) and (3) and Figure 2. $\left(x_{CP}\right)_f / d$ of Equation (19) is defined by Equation (10) and Figure 3. Finally, since Figure 2 already includes the approximate reference areas, Equation (19) is appropriate as it stands. Equation (19) only includes that portion of the flare area external to the cylindrical part of the body (see Equation (1)). This is because the body alone pitch damping moment discussed in Section 2.2 already includes the cylindrical part of the afterbody.

3.0 RESULTS AND DISCUSSION

3.1 STATIC AERODYNAMICS OF FLARED CONFIGURATION

In this section of the report, we will show the comparison of the approximate methods to predict aerodynamics of flared configurations to both CFD and experimental results. Static aerodynamic predictions of flared configurations will be considered first. Unfortunately, the author was only able to find data in the literature for Mach numbers of 2.0 and greater. Hence, the new inclusion into the APC of flare static aerodynamics for $M_\infty < 1.2$ cannot be validated at present. However, existing static aerodynamic predictions for low supersonic to hypersonic Mach numbers can be assessed. It is suspected that the reason for the lack of static aerodynamic data at low Mach numbers for flare stabilized configurations is that the practical application of flare configurations is at high Mach number. This is because fins lose their effectiveness as stabilizing devices as Mach number increases, along with posing problems for leading edge heating and ablation. On the other hand, flares are just as effective at high Mach number as at low Mach number in providing stability, although they give high drag compared to fins, particularly at low Mach number.

The first case considered for static aerodynamics validation is shown in Figure 4 and is taken from Reference 15. This configuration is a blunted Von Karman ogive-cylinder-flare case with a 10 deg, 2 caliber flare. Wind tunnel data was taken at $M_\infty = 2.0$ and R_N/ft of 2×10^6 without a boundary layer trip present. Comparison of the theory (here shown as AP02) to experiment for the forebody axial force, normal force, and pitching moment coefficients is given

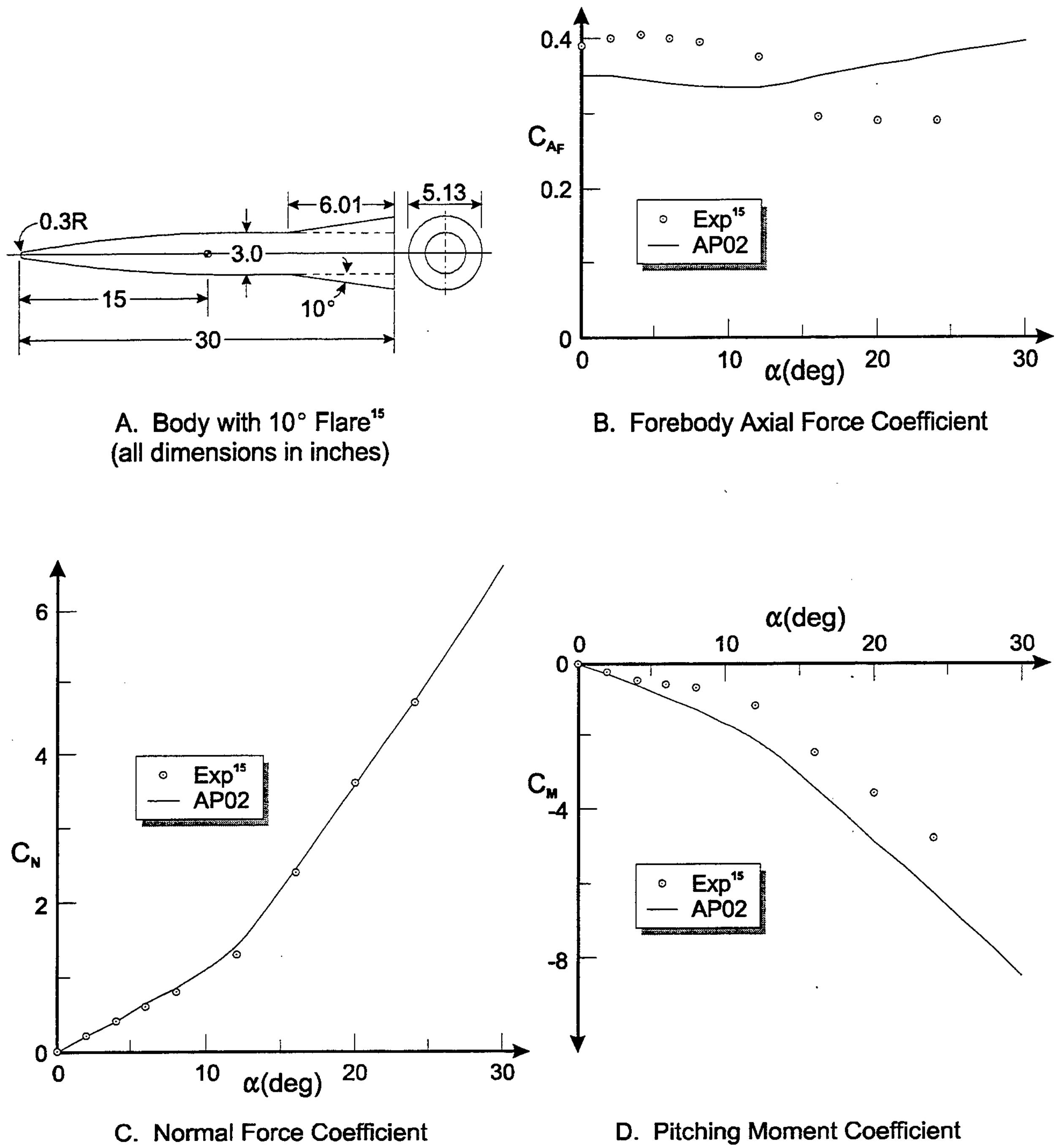


FIGURE 4. COMPARISON OF THEORY AND EXPERIMENT FOR STATIC AERODYNAMICS OF A BODY-FLARE CONFIGURATION ($M_\infty = 2.01$, $R_N/ft = 2\times10^6$)

in the figure. The axial force is not as accurate as desired. However, this could be due to the fact that the base pressure term was subtracted from the total axial force. This term was larger than the friction and wave drag terms combined. Hence, a small error in measuring the base pressure of 5 to 10 percent could account for most or all of the discrepancy between theory and

experiment for the axial force coefficient of Figure 4B. Normal force predictions are excellent and pitching moments are quite acceptable. The average center of pressure error is less than 4 percent of the body length, which means the predictions are within the ±4 percent of body length error bound accuracy goal stated for the AP02. The average normal force error is under 2 percent. Since no total axial force measurements were given, an accuracy assessment on the axial force cannot be given.

The second case considered is a fairly short (5.84 calibers), cone-cylinder-flare configuration called the CAN4 projectile.[16] A schematic of the configuration is shown at the top of Figure 5. Figure 5 also gives the axial force coefficient along with the normal force and pitching moment coefficient slopes near $\alpha = 0$ deg. Ballistic range data consists of several tests around $M_\infty = 4.5$ and 5.75. These data points were fairly closely scattered together and fairly close in value so an approximate average is shown on Figure 5 at the Mach numbers of 4.5 and 5.75. As seen in the figure, the AP02 calculations are about 6 to 8 percent lower than the ballistic range for axial force, within 1 percent of ballistic range data for C_{N_α} and predicts C_{M_α} as being too stable. In terms of center of pressure, the error in C_{M_α} will give the center of pressure error as less than 2 percent of the body length, or about 0.1 caliber. All these errors are well within the stated accuracy goals on static aerodynamics of ±10 percent on axial and normal force coefficient and ±4 percent of the body length for center of pressure.

The third case considered for static aerodynamics of flared projectiles is shown in Figure 6 and is called CAN1A projectile.[17] It is also a very short configuration (6.06 calibers) with a very large flare angle (27.6 deg). It was tested in the wind tunnel at $M_\infty = 8.2$ from α of −10 deg to +10 deg. The experimental data of Reference 17, along with the AP02 computations and Missile Datcom Computations (also obtained from Reference 17) are given in Figure 6. Coefficients given in Figure 6 include lift, drag, and pitching moment. Both the approximate codes gives reasonable predictions for all the aerodynamics with the AP02 and Missile Datcom giving about equal predictions for pitching moment. However, the AP02 is slightly more accurate than the Missile Datcom for both axial force and lift force coefficient predictions. Neither of the approximate codes predicts the nonlinearity in aerodynamics that occurs due to the flow separation behind the shoulder of the cone and ahead of the flare. This nonlinearity is primarily evident between ±8 deg AOA.

The last flared configuration where static aerodynamics were found in the literature is shown in Figure 7. It is a very long (23.14 calibers) configuration with a flare that is 4.24 calibers in length and flare angle that varies from 0 to 20 deg. Data were given in Reference 18 at $M_\infty = 4.4$, 5.9, and 8.8. All three cases showed similar trends and the AP02 predictions were similar, so only the $M_\infty = 5.9$ case is shown in Figure 7. Aerodynamics shown include the forebody axial force coefficient and the normal force and pitching moment slopes near $\alpha = 0$ deg. No experimental data was given in Reference 18, only Parabolized Navier-Stokes (PNS) calculations at sea level conditions where fully turbulent flow was assumed. The AP02 predictions agree quite well with the PNS calculations for all the aerodynamic coefficients at all flare angles.

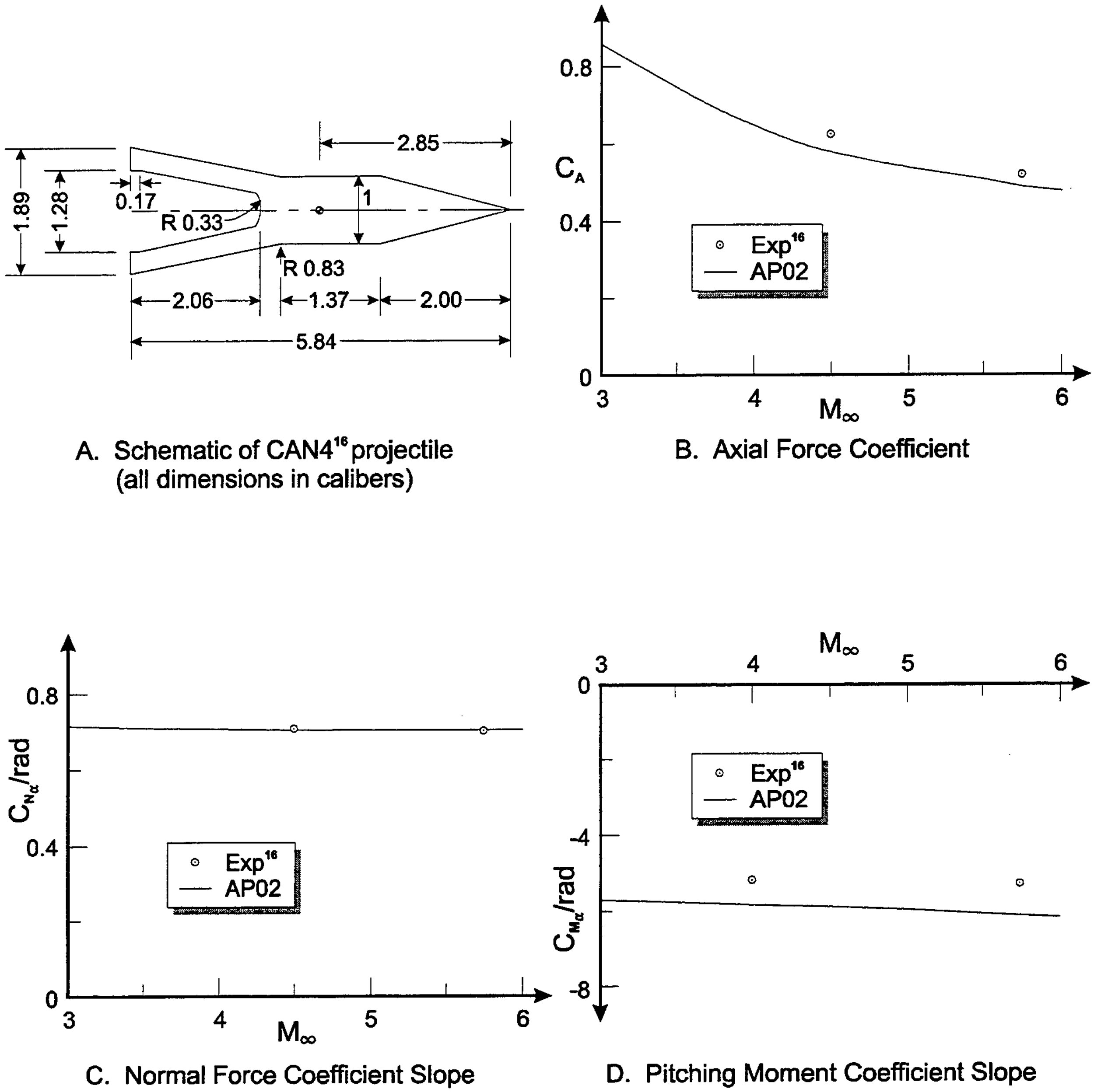


FIGURE 5. STATIC AERODYNAMICS OF THE CAN4 PROJECTILE AT HIGH MACH NUMBER

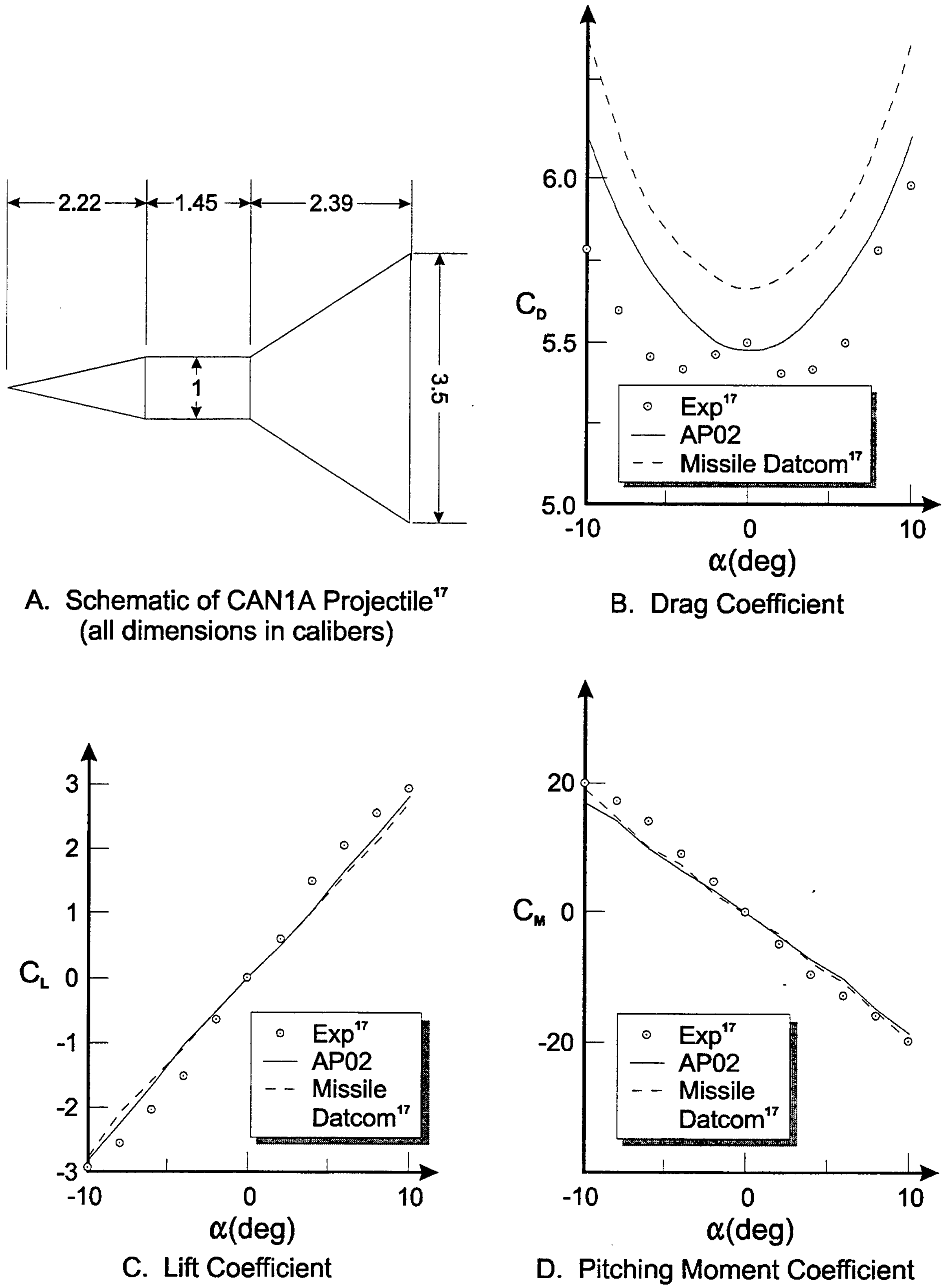
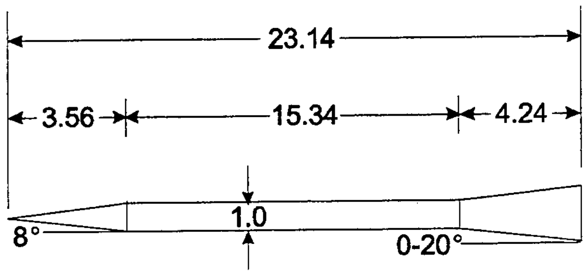
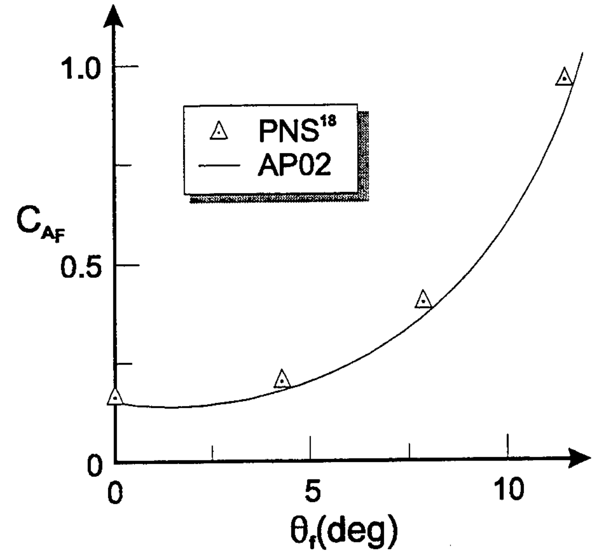


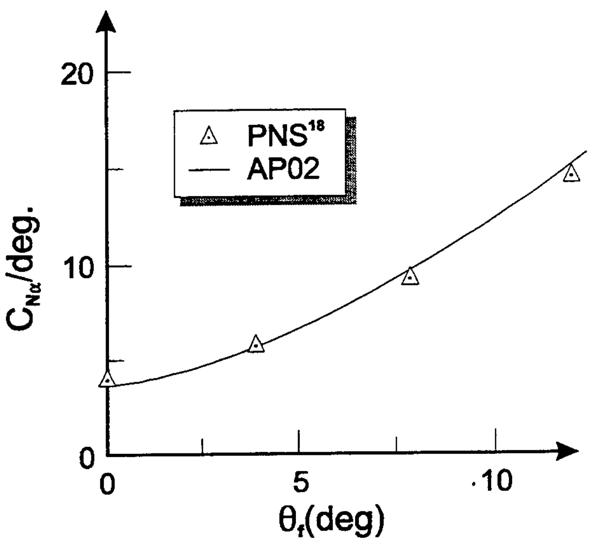
FIGURE 6. STATIC AERODYNAMICS OF THE CAN1A PROJECTILE AT $M_\infty = 8.2$



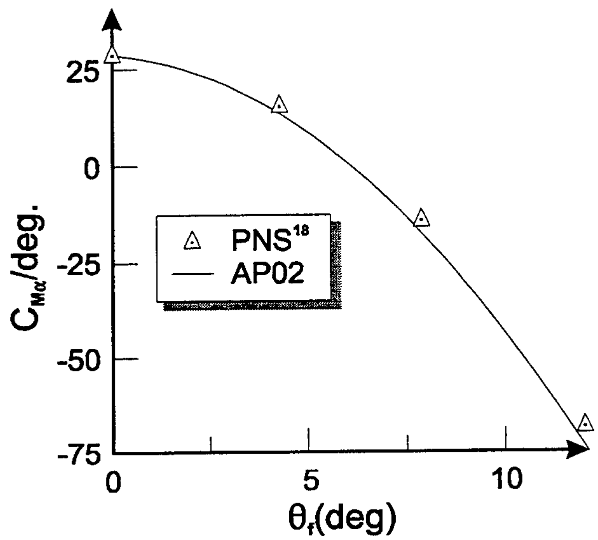
A. Schematic of F829 Cone-Cylinder-Flare Configuration[18] (all dimensions in calibers) (one caliber=27.05 mm)



B. Forebody Axial Force Coefficient



C. Normal Force Coefficient Slope



D. Pitching Moment Coefficient Slope

FIGURE 7. STATIC AERODYNAMICS OF F829 CONFIGURATION ($M_\infty = 5.9$, $\alpha \approx 0$ deg)

3.2 PITCH DAMPING MOMENT OF BODY ALONE CONFIGURATIONS

The next aerodynamic term to be considered in the validation process is body alone pitch damping moment where no flare is present. The modifications to the AP98 predictions (which are basically taken from the old GE Spinner program[13] were discussed in Section 2.2 of this report. A recent report from the Army Research Laboratory (Reference 9) showed PNS

calculations of pitch damping on a 5, 6, and 7 caliber configuration with (SOCBT) and without a boattail (SOC). Computations were available from $M_\infty = 2$ to 5. These results were instrumental in the author concluding that the AP98 pitch damping computations for a body alone needed improvement for higher Mach numbers. Figure 8 shows the comparison of the Section 2.2 improvements in the AP02 compared to the AP98 predictions and PNS predictions for pitch damping moment. While the AP02 does not agree perfectly with the PNS computations, it shows drastic improvement over the AP98 for $M_\infty \geq 2.0$ at all the body lengths (5, 6, and 7 calibers) shown in Figure 8. The center of gravity was held to a constant percent of the total body length of 60 percent in these calculations. A note of caution is given here to the reader. The Reference 9 (and all Army results) use a nondimensionalization of qd/V_∞ for the pitch damping whereas the Navy uses $qd/(2V_\infty)$. Hence, all Army results had to be multiplied by 2 to compare to Navy results.

Figure 9 gives the complimentary results for the SOCBT case. Here, the AP02 predictions agree much closer to the PNS calculations than for the SOC configuration. For both the SOC and SOCBT cases, the AP02 predictions are much closer to the PNS computations than are the AP98 calculations.

The last body alone case considered for validation of the improved pitch damping predictions is given in Figure 10. This configuration is the Army-Navy-Spinner (ANSR) case which consists of a 2.0 caliber tangent ogive nose followed by a 3, 5, and 7 caliber cylindrical afterbody. Total body lengths are therefore 5, 7, and 9 calibers. Results were given in References 9 and 10 consisting of PNS calculations and ballistic range data. Data were available for all configurations for M_∞ between 1.3 and 2.5 and for the 7 caliber case, for M_∞ between 0.8 and 2.5. Also several center of gravity locations were given in References 9 and 10, but only the case where the center of gravity was at about the 60 percent location (which is typical of most ammunition) is shown here. A couple of points are of interest. First of all, for Mach numbers below about 1.5, the old AP98 predicts pitch damping quite adequately. Also for Mach numbers as high as 2.5, predictions are not that bad for the AP98, so only minor improvements are shown using the AP02 for this configuration due to the low Mach numbers considered. This makes sense because the Reference 13 methodology was based on available data, which in the 1970's consisted mainly of shells with $0.8 \leq M_\infty \leq 2.5$ and lengths of 4 to 7 calibers. The second point to note from Figure 10 is that for the longest configuration ($\ell = 9$ calibers), there is a large scatter in the ballistic range data, but the predictions still appear to be reasonable, given the large scatter in data.

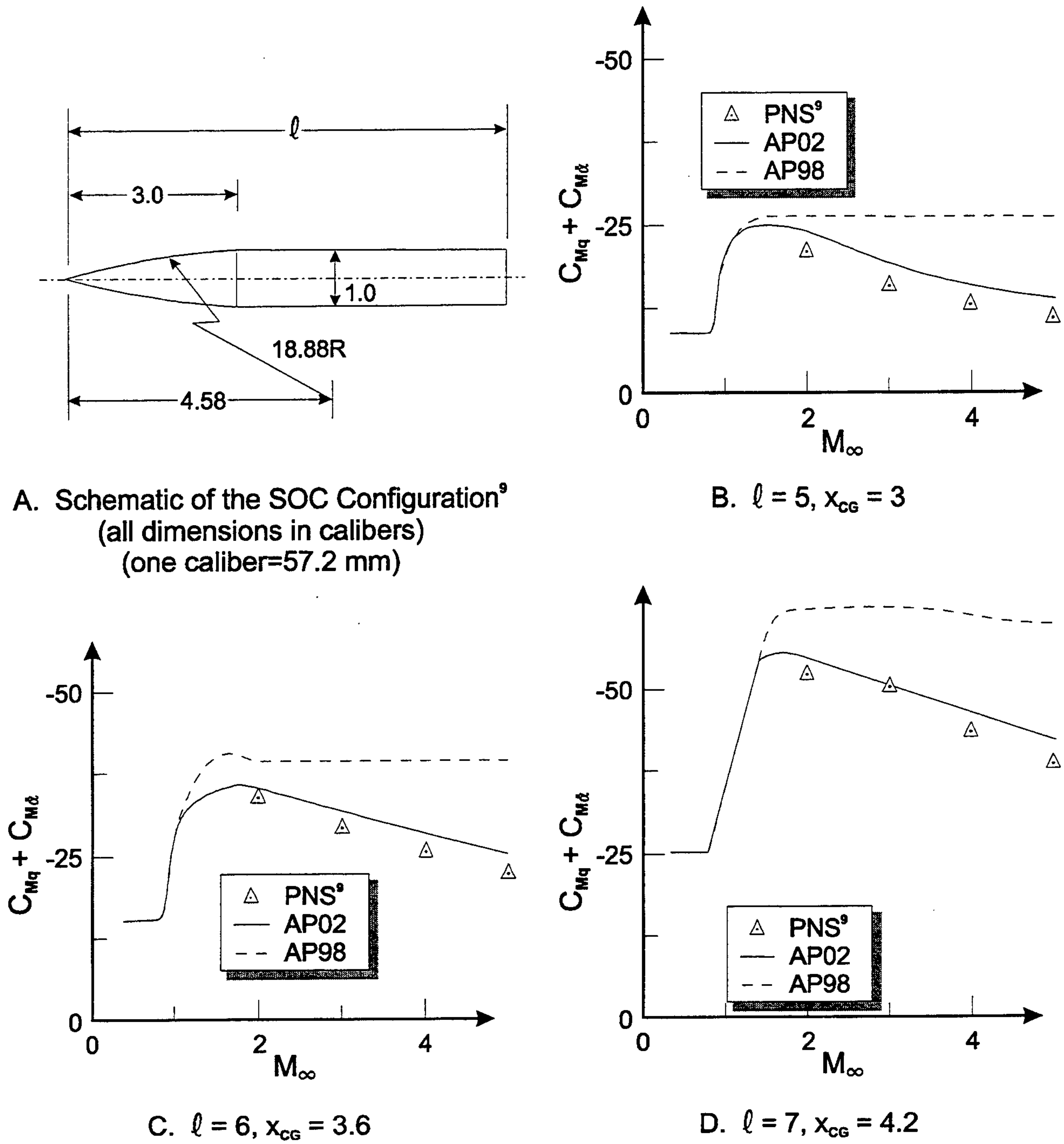
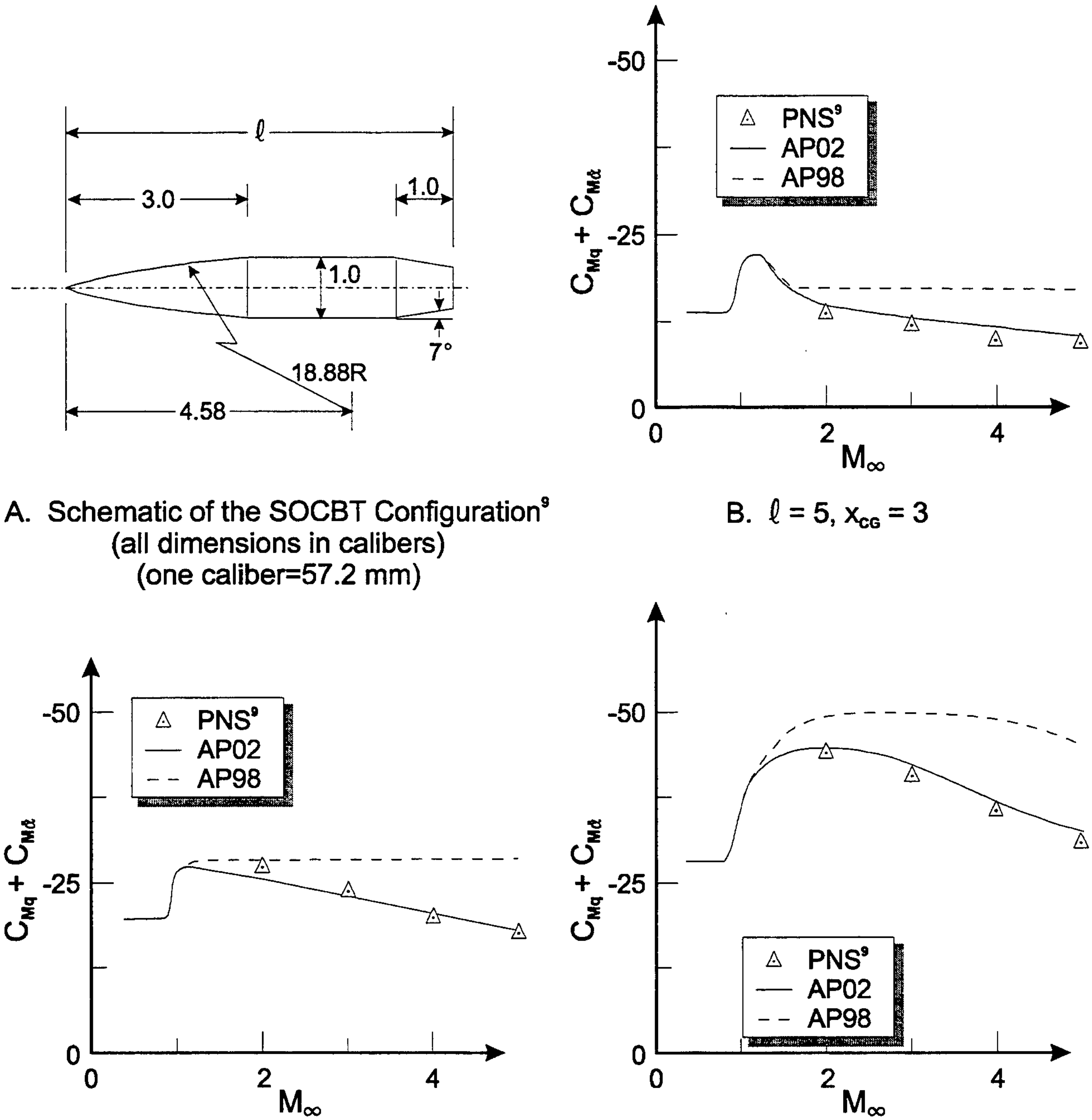


FIGURE 8. PITCH DAMPING MOMENT COEFFICIENT PREDICTIONS FOR THE SOC CONFIGURATION



A. Schematic of the SOCBT Configuration[9]
(all dimensions in calibers)
(one caliber=57.2 mm)

B. $\ell = 5$, $x_{CG} = 3$

C. $\ell = 6$, $x_{CG} = 3.6$

D. $\ell = 7$, $x_{CG} = 4.2$

FIGURE 9. PITCH DAMPING MOMENT COEFFICIENT PREDICTIONS FOR THE SOCBT CONFIGURATION

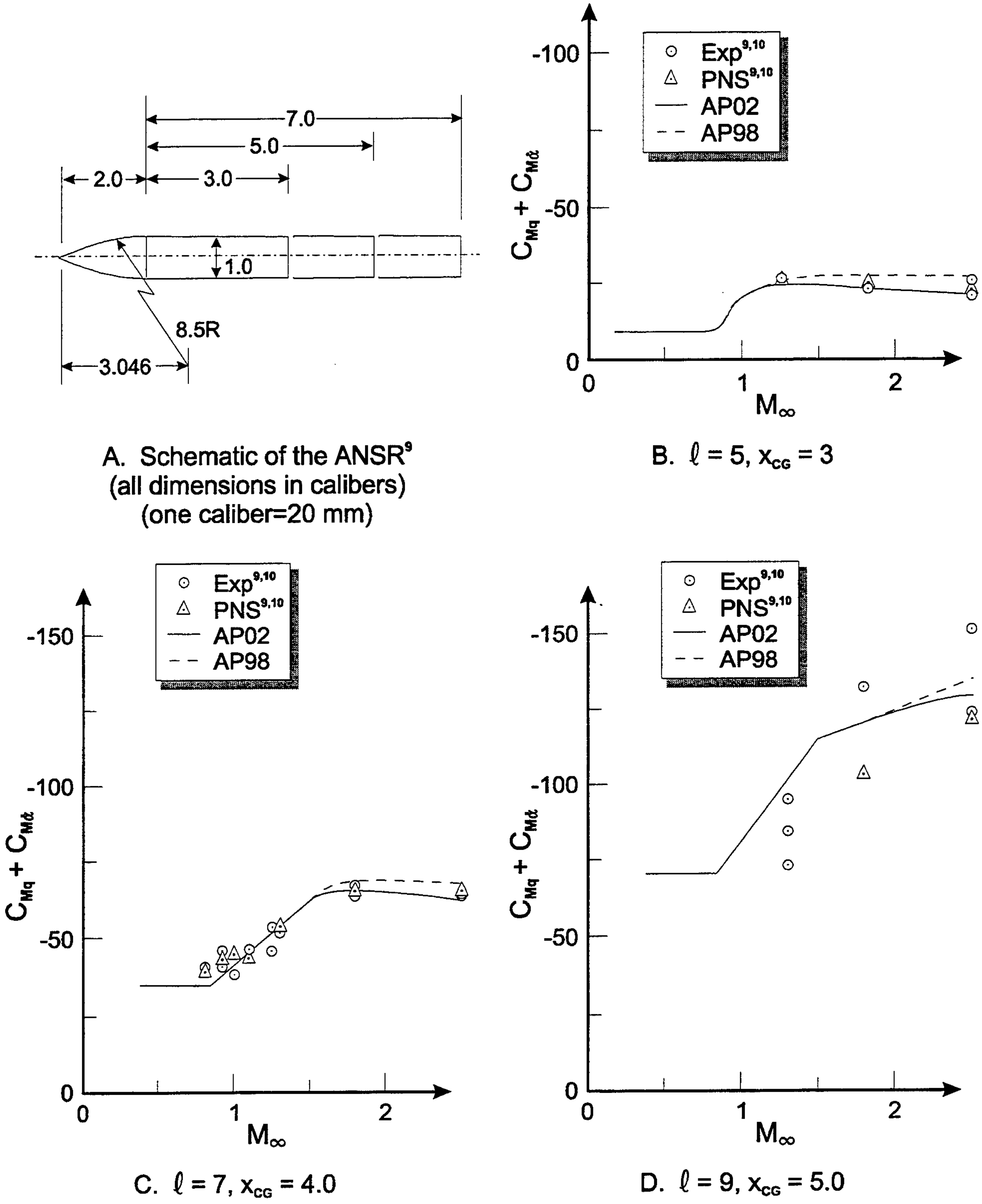


FIGURE 10. PITCH DAMPING MOMENT COEFFICIENT PREDICTIONS COMPARED TO EXPERIMENT FOR ANSR

3.3 PITCH DAMPING OF FLARED CONFIGURATIONS

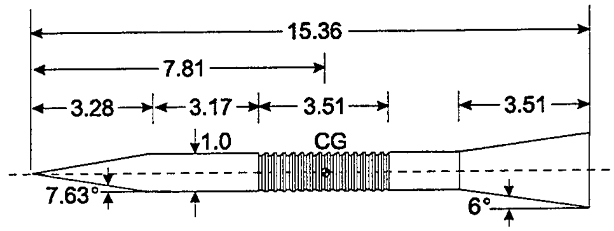
We are now ready to validate the AP02 predictions of pitch damping moment for flare configurations. Recall that this was the primary reason for this report and the improvements to the AP98, as the AP98 did not give any additional pitch damping due to the presence of a flare. Figure 11 gives the first case considered. It is termed the CS-V4-1 configuration in Reference 7. This configuration consists of a blunt cone-cylinder-flare, where the flare angle is 6 deg and the flare length is 3.51 calibers. The overall configuration length is 15.36 calibers. The configuration of Figure 11 shows rifling grooves, but a smooth body was assumed in the PNS and aeroprediction calculations. Pitch damping results are shown in Figure 11 for Mach numbers 0.4 to 5.0 from the AP02 and AP98. PNS results are shown from $M_\infty = 3$ to 4.5 and ballistic range results are shown at $M_\infty = 4.0$. Note the AP02 methodology agrees much closer to the experimental data and PNS results than does the AP98. The AP98 results are basically those of a cone-cylinder that is 15.36 calibers long.

Figure 12 shows pitch damping results for a configuration similar to that of Figure 11, except the flare is longer, 4.49 versus 3.51 calibers, and the overall Figure 12 configuration length is longer (16.34 versus 15.36 calibers) than that of Figure 11. Again, AP98 and AP02 results are shown for Mach number of 0.4 to 5 whereas PNS calculations were available for Mach number of 3 to 4.5 and ballistic range data was available for $M_\infty = 4.0$ only. The AP02 results match the PNS calculations quite nicely with the AP98, being much lower than the PNS results due to not accounting for the flare. The ballistic range data are somewhat lower than the PNS data and AP02 for this configuration, possibly due to the impact of the grooves on the pitch damping.

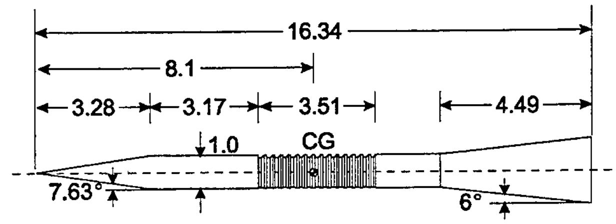
The third case considered for pitch damping is the CAN4 projectile which was previously considered for static aerodynamics in Figure 5. The pitch damping results are shown in Figure 13 in terms of AP98 and AP02 for Mach numbers 2 to 6 and CFD and ballistic range results at $M_\infty = 4.4$ and 5.72. The AP02 results agree very well with the CFD results and both are 10 to 15 percent lower than the experimental data. Errors of ±20 percent are quite reasonable and so these results are quite acceptable for dynamic derivative predictions. However, the older AP98 gives unacceptable results.

The fourth flared configuration where experimental pitch damping data or CFD computations was found in the literature is shown in Figure 14.[6] This configuration is also a cone-cylinder-flare of 12.28 calibers total length. It has a flare with a 15 deg flare angle that is 2.67 calibers in length. Only one CFD data point was given in Reference 6 at $M_\infty = 4.4$ in. However, AP02 and AP98 computations are shown for Mach numbers of 2 to 6.0. The AP02 results are about 12 percent lower than the data point at $M_\infty = 4.4$ ($C_{M_q} + C_{M_{\dot{\alpha}}} = -550$ versus -625), which is considered to be acceptable prediction accuracy. However, the AP98 predictions are about 60 percent too low.

The final configuration where CFD or experimental pitch damping data was found was also taken from Reference 6 and results are given in Figure 15. It consists of a 13.16 caliber cone-cylinder-flare where the flare angle varies from 4 to 14 deg. Again, only $M_\infty = 4.4$ data was



CS-V4-1 Flare Stabilized Projectile Geometry[7]
(all dimensions in calibers)
(one caliber=8.28 mm)



CS-V4-2 Flare Stabilized Projectile Geometry[7]
(all dimensions in calibers)
(one caliber=8.28 mm)

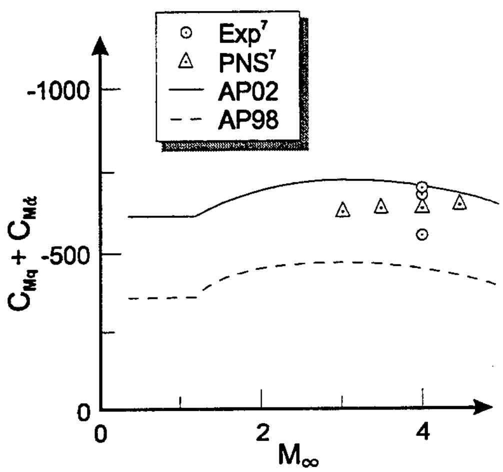


FIGURE 11. COMPARISON OF THEORY AND EXPERIMENT FOR PITCH DAMPING MOMENT COEFFICIENT OF CS-V4-1 CONFIGURATION

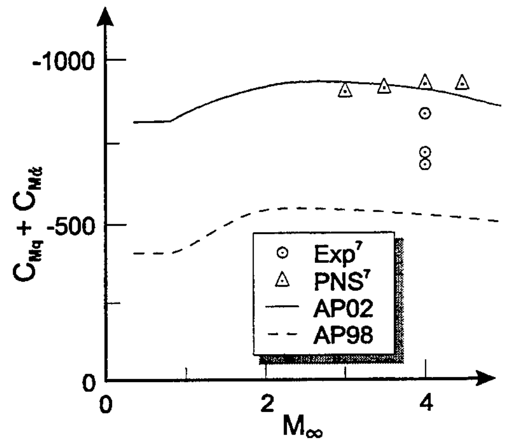
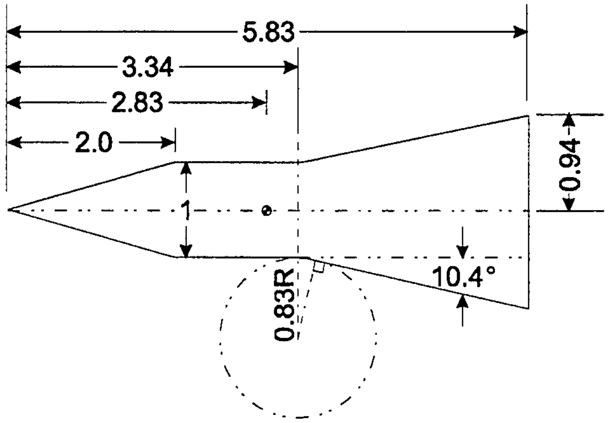
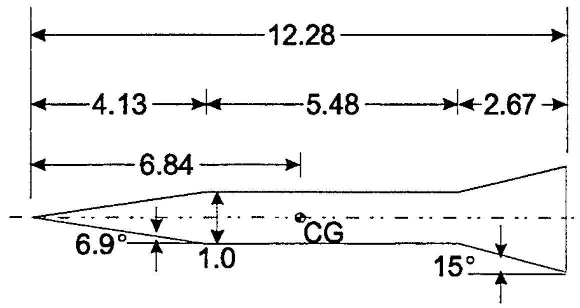


FIGURE 12. COMPARISON OF THEORY AND EXPERIMENT FOR PITCH DAMPING MOMENT COEFFICIENT OF CS-V4-2 CONFIGURATION



CAN4[8] Projectile Schematic
(all dimensions in calibers)



Flared Projectile Configuration[6]
(all dimensions in calibers)

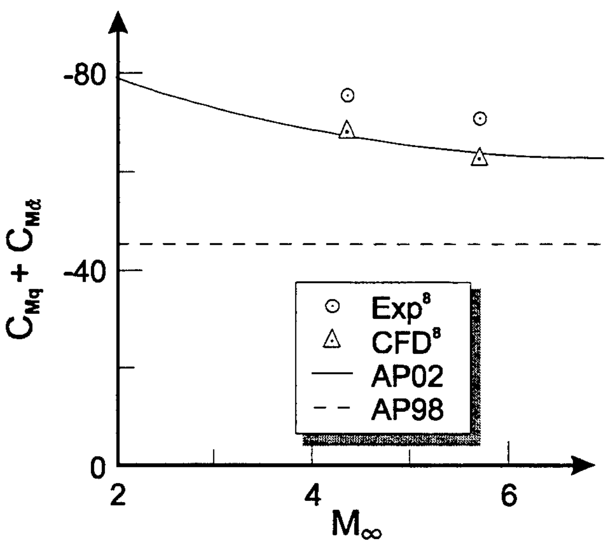


FIGURE 13. COMPARISON OF THEORY AND EXPERIMENT FOR PITCH DAMPING MOMENT COEFFICIENT OF CAN4 PROJECTILE

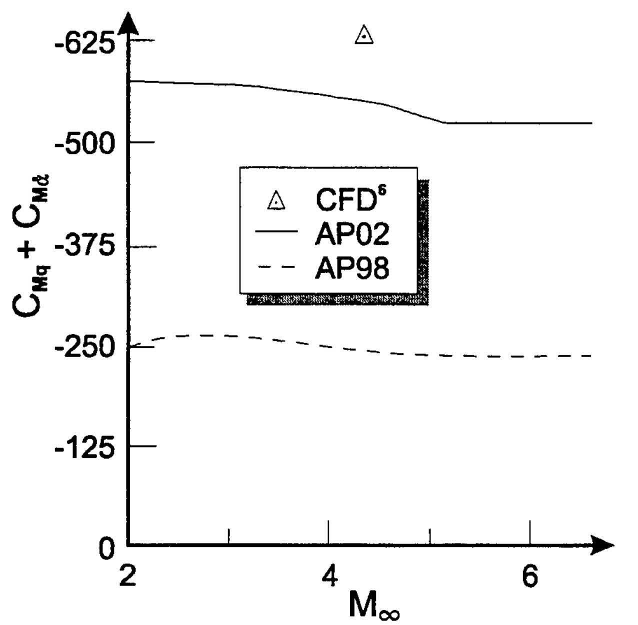
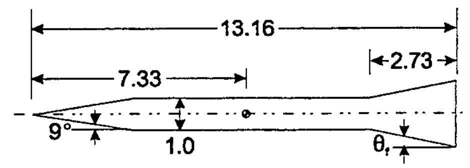


FIGURE 14. COMPARISON OF THEORY FOR PITCH DAMPING MOMENT COEFFICIENT OF FLARED PROJECTILE CONFIGURATION



Control Projectile Configuration[6]
(all dimensions in calibers)

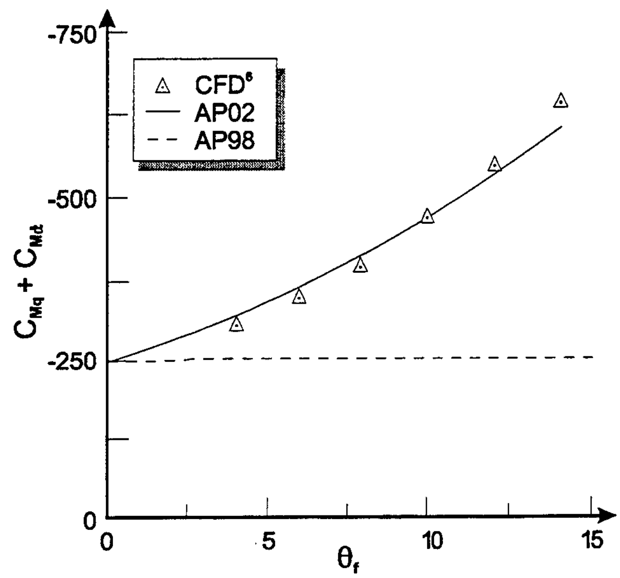


FIGURE 15. COMPARISON OF THEORETICAL PREDICTIONS OF PITCH DAMPING MOMENT COEFFICIENT FOR VARIOUS FLARE ANGLES ($M_\infty = 4.4$)

given in Reference 6. Notice the good agreement of the AP02 to the CFD computations. Here the worst error of the AP02 compared to the CFD is under 6 percent for the $\theta_f = 14$ deg case. Again, the AP98 gives unacceptable agreement to the CFD, except for small θ_f.

4.0 SUMMARY AND CONCLUSIONS

To summarize, new capability has been added to the NSWC aeroprediction code to allow static aerodynamics to be computed for flared configurations at all Mach numbers. Improvements have been added to pitch damping predictions for high Mach numbers for body alone configurations (no flare present). Finally, new capability has been added to allow pitch damping computations to be made for flare configurations for all Mach numbers where the aeroprediction code is operational (Mach numbers 0 to 20).

In comparing the new aeroprediction code (AP02) to experimental data and both Parabolized and Full Navier-Stokes predictions, the following conclusions were drawn:

a) Comparison of static aerodynamic predictions for configurations that have flares to experimental data and CFD computations appears to show the AP98 and AP02 give predictions within the standard accuracy goals for configurations with wings or tails. That is average accuracy of ±10 percent for axial and normal force and ±4 percent of the body length for center of pressure.

b) Comparison of AP02 pitch damping predictions for bodies without flares to the AP98, experimental data and CFD computations showed the AP02 predictions to be superior to the AP98 for $M_\infty > 2$ for all cases considered. The average accuracy goal of ±20 percent was met for the AP02 but not with the AP98.

c) Comparison of the AP02 pitch damping predictions for bodies with flares to the AP98, experimental data and CFD computations showed the AP02 predictions to be within the desired average accuracy goal of ±20 percent, whereas the AP98 could be off as much as 60 to 70 percent due to failure to account for the flare.

d) No data (either static or dynamic) was found for flared configurations for Mach numbers below 2.0. Hence, the new capability for both static aerodynamics for $M_\infty < 1.2$ and pitch damping for flared configurations could not be adequately validated for low Mach numbers. While the author would like to have data for validation in this Mach number range, it is impractical from a usage standpoint. This is due to the fact that fins are better at both stability and drag for moderate supersonic Mach numbers and lower than flares.

e) While the pitch damping methods for flared configurations have not been validated for Mach numbers below 2.0, the author believes they can still be used with confidence in preliminary design tradeoffs to compare flared configurations to those with wings. This is due to the accuracy of the methodology for Mach numbers above 2.0 and the consistency of the methodology for Mach numbers above and below 2.0.

5.0 REFERENCES

1. Moore, F. G.; McInville, R. M.; and Hymer, T., *The 1998 Version of the NSWC Aeroprediction Code: Part I – Summary of New Theoretical Methodology*, NSWCDD/TR-98/1, Apr 1998.

2. Moore, F. G.; McInville, R. M.; and Robinson, D. I., *A Simplified Method for Predicting Aerodynamics of Multi-Fin Weapons*, NSWCDD/TR-99/19, Mar 1999.

3. Moore, F. G. and McInville, R. M., *Refinements in the Aeroprediction Code Based on Recent Wind Tunnel Data*, NSWCDD/TR-99/116, Dec 1999.

4. Allen, J. M.; Hemsch, M. J.; Burns, K. A.; and Oeters, K. J., *Parametric Fin-Body and Fin-Alone Database on a Series of 12 Missile Fins*, NASA LRC TM in publication, May 1996.

5. Hymer, T. C.; Downs, C.; and Moore, F. G., *Users Guide for an Interactive Personal Computer Interface for the 1998 Aeroprediction Code (AP98)*, NSWCDD/TR-98/7, Jun 1998.

6. Sturek, W. B.; Nietubicz, C. J.; Sahu, J.; and Weinacht, P., *Recent Applications of CFD to the Aerodynamics of Army Projectiles*, ARL-TR-22, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, Dec 1992.

7. Weinacht, P., *Navier-Stokes Predictions of Pitch-Damping for a Family of Flared Projectiles*, ARL-TR-591, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, Oct 1994.

8. Qin, N.; Ludlow, D. K.; Shaw, S. T.; Edwards, J. A.; and Dupuis, A., "Calculation of Pitch Damping Coefficients for Projectiles," AIAA paper no. 97-0405, 35th Aerospace Sciences Meeting, Jan 1997.

9. Weinacht, P.; Sturek, W. B.; and Schiff, L. B., *Navier-Stokes Predictions of Pitch-Damping for Axisymmetric Shell Using Steady Coming Motion*, ARL-TR-575, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, Sep 1994.

10. Weinacht, P., "Prediction of Pitch-Damping of Projectiles at Low Supersonic and Transonic Velocities," AIAA paper no. 98-0395, 36th Aerospace Sciences Meeting, Reno, NV, Jan 1998.

REFERENCES (Continued)

11. Wu, J. M. and Aoyoma, K., *Transonic Flow-Field Calculation Around Ogive Cylinders by Nonlinear – Linear Stretching Method*, U.S. Army Missile Command Technical Report RD-TR-70-12, April 1970. Also AIAA 8th Aerospace Sciences Meeting, AIAA paper 70-189, Jan 1970.

12. Ames Research Staff, *Equations, Tables, and Charts for Compressible Flow*, NACA Report 1135, 1953.

13. Whyte, R. H., *Spinner – A Computer Program for Predicting the Aerodynamic Coefficients of Spin Stabilized Projectiles*, General Electric Class 2 Reports, 1969.

14. Chin, S. S., *Missile Configuration Design*, McGraw Hill Book Company, Inc., New York, NY, 1961, pp. 134-138

15. Robinson, R., *Wind Tunnel Investigation at a Mach Number of 2.01 of the Aerodynamic Characteristics in Combined Angles of Attack and Sideslip of Several Hypersonic Missile Configurations with Various Canard Controls*, NACA RM L58A21, Mar 1958.

16. Dupuis, A. and Edwards, J. A., "Analysis of Free-Flight Data for the CAN4 Hypersonic Research Projectile," AIAA paper no. 98-0581, 36th Aerospace Sciences Meeting, Reno, NV, Jan 1998.

17. Edwards, J. A.; Cleaves, J. A.; Roper, J. J.; and Dupuis, A. D., "Wind Tunnel Tests and Computational Analysis of the CAN1A Projectile at Mach 8.2," AIAA paper no. 96-0461, 34th Aerospace Sciences Meeting, Reno, NV, Jan 1996.

18. Guidos, B. J., *Static Aerodynamics CFD Analysis for 120-mm Hypersonic KE Projectile Design*, ARL-MR-184, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, Sep 1994.

6.0 SYMBOLS AND DEFINITIONS

AOA	Angle of Attack
APC	Aeroprediction Code
AP02, AP98	2002 and 1998 versions of the APC, respectively
CFD	Computational Fluid Dynamics
NSWCDD	Naval Surface Warfare Center, Dahlgren Division
PNS	Parabolized Navier-Stokes
SB, SBT	Slender Body, Slender-Body Theory
A_{REF}	Reference area (maximum cross-sectional area of body, if a body is present, or planform area of wing, if wing alone)(ft^2)
A_B	Base area = $\pi d_B^2 / 4$
C_A	Axial force coefficient
$C_{A_B}, C_{A_f}, C_{A_W}$	Base, skin-friction, and wave components, respectively, of axial force coefficient
C_{A_F}	Forebody axial force coefficient $\left(C_{A_F} = C_{A_f} + C_{A_W}\right)$
C_D	Drag coefficient
C_L	Lift coefficient
C_M	Pitching moment coefficient (based on reference area and body diameter, if body present, or mean aerodynamic chord, if wing alone)
C_{M_α}	Pitching moment coefficient derivative (per radian)

$C_{M_q} + C_{M_{\dot{\alpha}}}$	Pitching damping moment coefficient $[C_M(q)/(qd/2V_\infty) + C_M(\dot{\alpha})/(\dot{\alpha}d/2V_\infty)]$
$C_M(q)$	Pitching moment coefficient due to a constant pitching rate of q
$C_M(\dot{\alpha})$	Pitching moment coefficient due to a constant vertical acceleration of $\dot{\alpha}$
C_N	Normal force coefficient
C_{N_α}	Normal-force coefficient derivative (per radian)
cal	Caliber(s) (one body diameter)
d_B	Body diameter (ft) at base
d_r	Reference body diameter (ft)
deg	Degree(s)
ℓ, ℓ_n, ℓ_a, ℓ_f	Body length, nose length, afterbody length, and flare length, respectively
ℓ_I	Distance from cone apex to flare-cylinder juncture
M_∞	Freestream Mach number
N	Normal force (lbs)
r	Local body radius (ft)
R_N	Reynolds number
V_∞	Freestream velocity (ft/sec)
x_{CP}, $\overline{x}_{CP}$	Center of pressure (in feet or calibers from some reference point that can be specified) in x direction
x,y,z	Axis system fixed with x along centerline of body
α	Angle of attack (deg)
Φ	Roll position of missile fins ($\Phi = 0$ deg corresponds to fins in the plus (+) orientation; $\Phi = 45$ deg corresponds to fins rolled to the cross (×) orientation)

θ_f	Flare angle (deg)

<u>Subscripts</u>

C	Cone
CG	Center of gravity
f	Flare
∞	Freestream conditions

DISTRIBUTION

	Copies
DOD ACTIVITIES (CONUS)	
ATTN CODE 35 (ZIMET)	1
CODE 351 (SIEGEL)	1
CODE 351 (CHEW)	1
CODE 332FD (LEKOUDIS)	1
CHIEF OF NAVAL RESEARCH BALLSTON CENTRE TOWER ONE 800 NORTH QUINCY ST ARLINGTON VA 22217-5660	
ATTN CODE 474T6OD (LOFTUS)	1
CODE 4732HOD (SMITH)	1
CODE 473COOD (PORTER)	1
CODE 47HOOOD (BOSS)	1
CODE 473COOD (MCMANIGAL)	1
CODE 47311OD (HOUSH)	1
CODE 47311OD (GLEASON)	1
CODE 4722EOD (JETER)	1
TECHNICAL LIBRARY	1
COMMANDER NAVAL AIR WARFARE CENTER WEAPONS DIVISION 1 ADMINISTRATION CIRCLE CHINA LAKE CA 93555-6001	
ATTN TECHNICAL LIBRARY	1
G RUDACILLE PMS 38012 7	1
COMMANDER NAVAL SEA SYSTEMS COMMAND 2531 JEFFERSON DAVIS HWY ARLINGTON VA 22242-5160	
ATTN TECHNICAL LIBRARY	1
COMMANDER NAVAL AIR SYSTEMS COMMAND 47122 LILJENCRANTZ ROAD UNIT 7 PATUXENT RIVER MD 20670-5440	

	Copies
ATTN C KLEIN	1
TECHNICAL LIBRARY	1
COMMANDER NAVAL AIR WARFARE CENTER WEAPONS DIVISION 521 9TH ST POINT MUGU CA 93042-5001	
ATTN T C TAI	1
M J MALIA	1
TECHNICAL LIBRARY	1
COMMANDER NSWC CARDEROCK DIVISION WASHINGTON DC 20034	
ATTN R M HOWARD	1
TECHNICAL LIBRARY	1
SUPERINTENDENT NAVAL POSTGRADUATE SCHOOL 1 UNIVERSITY CIRCLE MONTEREY CA 93943-5001	
ATTN HEAD WEAPONS DEPT	1
HEAD SCIENCE DEPT	1
SUPERINTENDENT UNITED STATES NAVAL ACADEMY 121 BLAKE RD ANNAPOLIS MD 21402-5000	
ATTN DIAG DT 4T (PAUL MURAD)	2
DIRECTOR DEFENSE INTELLIGENCE AGENCY WASHINGTON DC 20301	
ATTN BRENT WAGGONER	1
CODE 4072 BLDG 2540 NAVAL WEAPONS SUPPORT CENTER CRANE IN 47522-5000	

DISTRIBUTION (Continued)

	Copies
ATTN CODE 5252P (KRAUSE)	1
TECHNICAL LIBRARY	1
COMMANDER	
INDIAN HEAD DIVISION	
NAVAL SURFACE WARFARE CENTER	
101 STRAUSS AVE	
INDIAN HEAD MD 20640-5035	
ATTN TECHNICAL LIBRARY	1
COMMANDING GENERAL	
MARINE CORPS COMBAT	
DEVELOPMENT COMMAND	
2048 SOUTH ST	
QUANTICO VA 22134-5129	
ATTN E SEARS	1
L E LIJEWSKI	1
C COTTRELL	1
TECHNICAL LIBRARY	1
AFATL (ADLRA) (DLGC)	1
EGLIN AFB FL 32542-5000	
ATTN TECHNICAL LIBRARY	1
USAF ACADEMY	
COLORADO SPRINGS CO 80912	
ATTN B BLAKE (BLD 146)	1
J JENKINS (BLD 146)	1
TECHNICAL LIBRARY	1
COMMANDING OFFICER	
AFSC	
2210 8TH STREET	
WRIGHT PATTERSON AFB OH 45433	
ATTN EDWARD JENKINS	1
NAIC TANW	
HQ NAIC TANW	
4115 HEBBLE CREEK ROAD SUITE 28	
WPAFB OH 45433-5623	
ATTN J USSELTON	1
W B BAKER JR	1
TECHNICAL LIBRARY	1
ARNOLD ENGINEERING DEVELOPMENT CENTER USAF	
TULLAHOMA TN 37389	

	Copies
ATTN H HUDGINS	1
G FRIEDMAN	1
AMSTA-AR-WEL-TL	1
COMMANDER	
US ARMY TACOM-ARDEC	
BUILDING 59 PHIPPS ROAD	
PICATINNY ARSENAL NJ 07806-5000	
ATTN R PUHALLA JR	1
W STUREK	1
C NIETUBICZ	1
A MIKHAIL	1
P PLOSTINS	1
TECHNICAL LIBRARY	1
COMMANDING GENERAL	
BALLISTIC RESEARCH LABORATORY	
ABERDEEN PROVING GROUND	
ABERDEEN MD 21005-5066	
ATTN CODE TNC (BLACKLEDGE)	1
RICH MATLOCK	1
DIRECTOR	
INTERCEPTOR TECHNOLOGY	
BALLISTIC MISSILE DEFENSE OFFICE	
THE PENTAGON	
WASHINGTON DC 20350	
ATTN SFAE SD ASP	1
SFAE SD HED	1
DEPUTY COMMANDER	
US ARMY STRATEGIC DEFENSE COMMAND	
P O BOX 1500	
HUNTSVILLE AL 35807-3801	
ATTN D WASHINGTON	1
W WALKER	1
R KRETZSCHMAR	1
D FERGUSON JR	1
COMMAND GENERAL	
US ARMY MISSILE COMMAND	
AMSMI RD SS AT	
REDSTONE ARSENAL AL 35898-5252	
DEFENSE TECHNICAL INFORMATION CENTER	
8725 JOHN J KINGMAN ROAD	
SUITE 0944	
FORT BELVOIR VA 22060-6218	2

DISTRIBUTION (Continued)

	Copies
DIRECTOR DEFENSE PRINTING SERVICE BLDG 176 WASHINGTON NAVY YARD 901 M ST E WASHINGTON DC 20374-5087	1
ATTN CODE A76 TECHNICAL LIBRARY	1
COMMANDING OFFICER CSSDD NSWC 6703 W HIGHWAY 98 PANAMA CITY FL 32407-7001	
ATTN DR P WEINACHT AERODYNAMICS BRANCH PROPULSION AND FLIGHT DIV WTD AMSRL WT PB US ARMY RESEARCH LAB ABERDEEN PROVING GROUND MD 21005-5066	1
ATTN GREGG ABATE US AIR FORCE WRIGHT LABORATORY WL MNAA 101 W EGLIN BLVD STE 219 EGLIN AFB FL 32542-5000	1
ATTN JOHN GRAU US ARMY ARDEC COMMANDER US ARMY ARDEC AMSTA AR AET A BLDG 3342 PICATINNY ARSENAL NJ 07806-5000	1
ATTN FRANK MACDONALD NAWC CHINA LAKE COMMANDER CODE 473 20D NAVAIRWARCENNSDNDIV CHINA LAKE CA 93555	1
ATTN MARK LAMBERT NAWC CODE 4732HOD CHINA LAKE CA 93555	1

	Copies
ATTN MICHAEL MUSACHIO DIRECTOR OFFICE OF NAVAL INTELLIGENCE 4251 SUITLAND ROAD (ONI 2321) WASHINGTON DC 20395	1
ATTN DR ALAN NICHOLSON MSC 5B DEFENSE INTELLIGENCE AGENCY MISSILE AND SPACE INTELLIGENCE CTR REDSTONE ARSENAL AL 35898-5500	1
ATTN EDWARD HERBERT US ARMY MISSILE COMMAND AMSMI RD MG GA BLDG 5400 ROOM 250 REDSTONE ARSENAL AL 35898	1
ATTN PAUL KOLODZIEJ NASA AMES RESEARCH CENTER MS 234 1 MOFFETT FIELD CA 94035	1
ATTN LCDR T HARTLINE USNR R NR ONI 2109 NAVAL RESERVE UNIT 112 CRESTVIEW CIRCLE MADISON AL 35758	1
ATTN CODE 4732HOD DAVID HALL PROPULSION PERFORMANCE OFFICE NAVAL AIR WARFARE CTR WEAPONS DIV 1 ADMINISTRATIVE CIR CHINA LAKE CA 93555-6001	1
ATTN DONALD SHEREDA WL FIMA BLDG 450 2645 FIFTH ST STE 30 WRIGHT PATTERSON AFB OH 45433-7936	1
BMDO AQS 1725 JEFFERSON DAVIS HWY STE 809 ARLINGTON VA 22202	1
ATTN JEFFREY RANDORF US ARMY SPACE AND STRATEGIC DEFENSE COMMAND P O BOX 1500 CSSD-BC-SS 106 WYNN DRIVE HUNTSVILLE AL 35807-3801	1

DISTRIBUTION (Continued)

	Copies
NON-DOD ACTIVITIES (CONUS)	
NICHOLS RESEARCH CORPORATION MS 912 P O BOX 400002 4040 S MEMORIAL PKWY HUNTSVILLE AL 35815-1502	1
THE CNA CORPORATION P O BOX 16268 ALEXANDRIA VA 22302-0268	1
GIDEP OPERATIONS OFFICE CORONA CA 91720	1
ATTN TECHNICAL LIBRARY	1
NASA AMES RESEARCH CENTER MOFFETT CA 94035-1099	
ATTN C SCOTT	1
D CURRY	1
NASA JOHNSON SPACE CENTER HOUSTON TX 77058	
ATTN TECHNICAL LIBRARY	1
NASA WASHINGTON DC 20546	
ATTN B HENDERSON	1
D MILLER	1
J ALLEN	1
F WILCOX	1
TECHNICAL LIBRARY	2
NASA LANGLEY RESEARCH CENTER HAMPTON VA 23365	
ATTN DR K JONES	1
NASA MARSHALL SPACE FLIGHT CTR CODE TD63 MSFC AL 35812	
ATTN D G MILLER (L 219)	1
TECHNICAL LIBRARY	1
LAWRENCE LIVERMORE NATIONAL LABORATORY EARTH SCIENCES DIVISION UNIVERSITY OF CALIFORNIA P O BOX 808 LIVERMORE CA 94551	

	Copies
ATTN W RUTLEDGE (1635)	1
R LAFARGE	1
R EISLER	1
TECHNICAL LIBRARY	1
SANDIA NATIONAL LABORATORY P O BOX 5800 ALBUQUERQUE NM 87185-5800	
ATTN WALT GUTIERREZ	1
SANDIA NATIONAL LABORATORIES MAIL STOP 0825 P O BOX 5800 ALBUQUERQUE NM 87185-0825	
ATTN ASSISTANT DEFENSE COOPERATION ATTACHE	1
EMBASSY OF SPAIN WASHINGTON DC 20016	
DE/AVT DEFENSE EQUIPMENT STAFF BRITISH EMBASSY 3100 MASSACHUSETTS AVE NW WASHINGTON DC 20008-3688	1
ATTN ASO LO IS	1
ISRAEL AIR FORCE LIAISON OFFICER 700 ROBBINS AVE PHILADELPHIA PA 19111	
ATTN GERMAN MILITARY REP US OA	1
GMR TRAFFIC AND TRANSPORTATION DIVISION 10 SERVICES ROAD DULLES INTERNATIONAL AP WASHINGTON DC 20041	
ATTN PROF F R DEJARNETTE	1
NORTH CAROLINA STATE UNIVERSITY DEPT OF MECHANICAL AND AEROSPACE ENGINEERING BOX 7921 RALEIGH NC 27695	
ATTN PROF J A SCHETZ	1
VIRGINIA POLYTECHNIC AND STATE UNIVERSITY DEPT OF AEROSPACE ENGINEERING BLACKSBURG VA 24060	

DISTRIBUTION (Continued)

	Copies
ATTN J M WU	1
C BALASUBRAMAYAN	1
TECHNICAL LIBRARY	1
THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE	
TULLAHOMA TN 37388	
ATTN R NELSON	1
TECHNICAL LIBRARY	1
UNIVERSITY OF NOTRE DAME	
DEPT OF AEROSPACE AND MECHANICAL ENGINEERING	
BOX 537	
NOTRE DAME IN 46556	
ATTN PROF F NELSON	1
DEPT OF MECH AND AERO ENG	
UNIVERSITY OF MISSOURI ROLLA	
ROLLA MO 65401	
ATTN ROBERT ENGLAR	1
GEORGIA TECH RESEARCH INSTITUTE	
AEROSPACE SCIENCE AND TECHNOLOGY LAB	
ATLANTA GA 30332	
ATTN E LUCERO	1
D FROSTBUTTER	1
L PERINI	1
TECHNICAL LIBRARY	1
APPLIED PHYSICS LABORATORY	
JOHNS HOPKINS UNIVERSITY	
JOHNS HOPKINS ROAD	
LAUREL MD 20723-6099	
ATTN B BROOKS	1
R STANCIL	1
R ELKINS	1
LORAL VOUGHT SYSTEMS	
P O BOX 650003	
M S EM 55	
DALLAS TX 75265-0003	
ATTN PROF J D ANDERSON	1
DEPT OF AEROSPACE ENGINEERING	
UNIVERSITY OF MARYLAND	
COLLEGE PARK MD 20742	

	Copies
ATTN TECHNICAL LIBRARY	1
HUGHES MISSILE SYSTEMS COMPANY	
P O BOX 11337 BLDG 802 MS A1	
OLD NOGALES HWY	
TUCSON AZ 83734-1337	
ATTN M DILLENIUS	1
NIELSEN ENGINEERING AND RESEARCH INC	
526 CLYDE AVE	
MOUNTAIN VIEW CA 95043	
ATTN J XERIKOS	1
N CAMPBELL	1
TECHNICAL LIBRARY	1
MCDONNEL DOUGLAS ASTRONAUTICS CO (WEST)	
5301 BOLSA AVE	
HUNTINGTON BEACH CA 92647	
ATTN J WILLIAMS	1
S VUKELICH	1
J FIVEL	1
R GERBSCH (CODE 1111041)	1
TECHNICAL LIBRARY	1
MCDONNELL DOUGLAS ASTRONAUTICS CO (EAST)	
BOX 516	
ST LOUIS MO 63166-0516	
ATTN TECHNICAL LIBRARY	1
UNITED TECHNOLOGIES	
NORDEN SYSTEMS	
NORWALK CT 06856	
ATTN T LUNDY	1
D ANDREWS	1
TECHNICAL LIBRARY	1
LOCKHEED MISSILES AND SPACE CO INC	
P O BOX 1103	
HUNTSVILLE AL 35807	
ATTN W CHRISTENSON	1
D WARNER	1
ALLIANT TECHSYSTEMS INC	
600 SECOND ST NE	
HOPKINS MN 55343	

DISTRIBUTION (Continued)

	Copies
ATTN TECHNICAL LIBRARY	1
B SALEMI	1
J BOUDREAU	1
RAYTHEON COMPANY	
MISSILE SYSTEMS DIVISION	
P O BOX 1201	
TEWKSBURY MA 01876-0901	
ATTN LLOYD PRATT	1
AEROJET TACTICAL SYSTEMS CO	
P O BOX 13400	
SACRAMENTO CA 95813	
ATTN JOSEPH ANDRZEJEWSKI	1
MEVATEC CORP	
1525 PERIMETER PARKWAY	
SUITE 500	
HUNTSVILLE AL 35806	
ATTN DR G S SCHMIDT	1
LORAL DEFENSE SYSTEMS	
1210 MASSILLON ROAD	
AKRON OH 44315-0001	
ATTN W NORDGREN 721	1
GOULD INC OSD	
18901 EUCLID AVE	
CLEVELAND OH 44117	
ATTN TECH LIBRARY	1
AEROJET ELECTRONIC SYSTEMS	
P O BOX 296 III	
AZUSA CA 91702	
ATTN P REDING	1
G CHRUSCIEL	1
TECHNICAL LIBRARY	1
LOCKHEED MISSILES AND SPACE CO INC	
P O BOX 3504	
SUNNYVALE CA 94088	
ATTN K C LEE	1
AEROTHERM CORP	
580 CLYDE AVE	
MOUNTAIN VIEW CA 94043	
ATTN TECH LIBRARY	1
FMC NAVAL SYSTEMS DIV	
4800 E RIVER ROAD	
MINNEAPOLIS MN 55421-1402	

	Copies
ATTN JAMES SORENSON	1
VINCENT ALLEN	1
ORBITAL SCIENCES	
3380 SOUTH PRICE ROAD	
CHANDLER AZ 85248	
ATTN J FORKOIS	1
KAMAN SCIENCES CORP	
1500 GARDEN OF THE GODS ROAD	
P O BOX 7463	
COLORADO SPRINGS CO 80933	
ATTN RON EFROMSON	1
MIT LINCOLN LABORATORY	
244 WOOD STREET	
LEXINGTON MA 02173-0073	
ATTN D J GIESE	1
MAIL STOP 4C 61	
BOEING DEFENSE AND SPACE GROUP	
P O BOX 3999	
SEATTLE WA 98124-2499	
ATTN BRIAN WALKUP	1
ALLEGHENY BALLISTICS LAB	
210 STATE ROUTE 956 WV01-13	
ROCKET CENTER WV 26726-3548	
ATTN DR T LIN	1
TRW ELECTRONICS AND DEFENSE SECTOR	
BLDG 527/RM 706	
P O BOX 1310	
SAN BERNADINO CA 92402	
ATTN G VINCENT	1
SPARTA INC	
4901 CORPORATE DR	
HUNTSVILLE AL 35805	
ATTN M S MILLER	1
N R WALKER	1
DYNETICS INC	
P O DRAWER B	
HUNTSVILLE AL 35814-5050	
ATTN H A MCELROY	1
GENERAL DEFENSE CORP	
P O BOX 127	
RED LION PA 17356	

DISTRIBUTION (Continued)

	Copies
ATTN ENGINEERING LIBRARY ARMAMENT SYSTEMS DEPT GENERAL ELECTRIC CO BURLINGTON VT 05401	1
ATTN TECHNICAL LIBRARY OAYNE AERONAUTICAL 2701 HARBOR DRIVE SAN DIEGO CA 92138	1
ATTN BRIAN EST BOEING ST LOUIS P O BOX 516 ST LOUIS MO 63166-0516	1
ATTN WILLIAM FACINELLI ALLIED SIGNAL P O BOX 22200 MS 1207 3B TEMPE AZ 85285	1
ATTN DR T P SHIVANANDA TRW BMD P O BOX 1310 SAN BERNADINO CA 92402-1313	1
ATTN T R PEPITONE AEROSPACE TECHNOLOGY INC P O BOX 1809 DAHLGREN VA 22448	1
ATTN ERIC MOORE MAIL STOP MER 24 1281 LOCKHEED SANDERS P O BOX 868 NASHUA NH 03061	1
ATTN DR BRIAN LANDRUM RI BLDG E33 PROPULSION RESEARCH CENTER UNIVERSITY OF ALABAMA HUNTSVILLE AL 35899	1
ATTN JIM ROBERTSON RESEARCH SOUTH INC 555 SPARKMAN DRIVE SUITE 818 HUNTSVILLE AL 35816-3423	1
ATTN BOB WHYTE ARROW TECH ASSOCIATES INC 1233 SHELBURNE ROAD D8 SO BURLINGTON VT 05403	1
ATTN JUAN AMENABAR SAIC 4001 NORTH FAIRFAX DRIVE STE 800 ARLINGTON VA 22209	1
ATTN TECHNICAL LIBRARY TELEDYNE RYAN AERONAUTICAL 2701 HARBOR DRIVE SAN DIEGO CA 92138	1
ATTN DR KIRIT PATEL SVERDRUP TECHNOLOGY INC TEAS GROUP BLDG 260 P O BOX 1935 EGLIN AFB FL 32542	1
ATTN FRANK LANGHAM MICRO CRAFT TECHNOLOGY 740 4TH ST MS 6001 ARNOLD AFB TN 37389	1
ATTN LAURA AYERS DELTA RESEARCH INC 315 WYNN DRIVE SUITE 1 HUNTSVILLE AL 35805	1
ATTN BRIAN BENNETT MCDONNELL DOUGLAS MC 064 2905 P O BOX 516 ST LOUIS MO 63166-0516	1
ATTN THOMAS FARISS LOCKHEED SANDERS P O BOX 868 MER24 1206 NASHUA NH 03061-0868	1
ATTN COREY FROST LOCKHEED MISSILES & SPACE CO INC P O BOX 070017 6767 OLD MADISON PIKE SUITE 220 HUNTSVILLE AL 35807	1

DISTRIBUTION (Continued)

	Copies
ATTN JEFFREY HUTH KAMAN SCIENCES CORPORATION 2560 HUNTINGTON AVE ALEXANDRIA VA 22303	1
ATTN WILLIAM JOLLY KAMAN SCIENCES 600 BLVD SOUTH SUITE 208 HUNTSVILLE AL 35802	1
ATTN STEPHEN MALLETTE KBM ENTERPRISES 15980 CHANEY THOMPSON RD HUNTSVILLE AL 35803	1
ATTN DONALD MOORE NICHOLS RESEARCH CORPORATION 4040 SOUTH MEMORIAL PARKWAY P O BOX 400002 MS 920C HUNTSVILLE AL 35815-1502	1
ATTN NANCY SWINFORD LOCKHEED MISSILES & SPACE CO P O BOX 3504 ORG E5-40 BLDG 1575E SUNNYVALE CA 94088-3504	1
ATTN DAVID RESSLER TRW BALLISTIC MISSILES DIV MS 953 2420 P O BOX 1310 SAN BERNARDINO CA 92402	1
ATTN MARK SWENSON ALLIANT TECHSYSTEMS MN11 262B 600 SECOND STREET NE HOPKINS MN 55343	1
ATTN LEROY M HAIR COLEMAN RESEARCH CORP 6820 MOQUIN DRIVE HUNTSVILLE AL 35806	1
ATTN SCOTT ALLEN ALLEN AERO RESEARCH 431 E SUNNY HILLS RD FULLERTON CA 92635	1

	Copies
ATTN DARRYL HALL SAIC 1100 FIRST AVENUE SUITE 300 KING OF PRUSSIA PA 19406	1
ATTN PETER ALEXANDER MCDONNELL DOUGLAS AEROSPACE 689 DISCOVERY DRIVE MS 11A1 HUNTSVILLE AL 35806	1
ATTN SAMUEL HICKS III TEXAS INSTRUMENTS 6600 CHASE OAKS BLVD MS 8490 PLANO TX 75086	1
ATTN BARRY LINDBLOM ALLIANT DEFENSE ELECTRONICS SYSTEMS INC P O BOX 4648 CLEARWATER FL 34618	1
ATTN DR SHIN CHEN THE AEROSPACE CORP M4 967 P O BOX 92957 LOS ANGELES CA 90009	1
ATTN EUGENE HART SYSTEM PLANNING CORP 1000 WILSON BLVD ARLINGTON VA 22209	1
ATTN ELAINE POLHEMUS ROCKWELL AUTONETICS & MISSILE SYSTEMS DIVISION D611 DL23 1800 SATELLITE BLVD DULUTH GA 30136	1
ATTN MICHAEL GLENN TASC 1992 LEWIS TURNER BLVD FT WALTON BEACH FL 32547	1

DISTRIBUTION (Continued)

	Copies
ATTN STEVEN MARTIN SYSTEMS ENGINEERING GROUP INC 9841 BROKEN LAND PARKWAY SUITE 214 COLUMBIA MD 21046-1120	1
ATTN C W GIBKE LOCKHEED MARTIN VOUGHT SYSTEMS MS SP 72 P O BOX 650003 DALLAS TX 75265-0003	1
ATTN CHRIS HUGHES EDO GOVERNMENT SYSTEMS DIV 1500 NEW HORIZONS BLVD AMITYVILLE NY 11701-1130	1
ATTN DANIEL LESIEUTRE NIELSEN ENGINEERING & RES INC 526 CLYDE AVENUE MOUNTAIN VIEW CA 94043-2212	1
ATTN CARL HILL	1
FRANCIS PRIOLO STANDARD MISSILE COMPANY LLC 1505 FARM CREDIT DRIVE SUITE 600 MCLEAN VA 22102	1
ATTN THOMAS LOPEZ COLEMAN RESEARCH CORP 990 EXPLORER BLVD HUNTSVILLE AL 35806	1
ATTN JENNIE FOX LOCKHEED MARTIN VOUGHT SYSTEMS P O BOX 650003 MS EM 55 DALLAS TX 75265-0003	1
ATTN JOHN BURKHALTER AUBURN UNIVERSITY 211 AEROSPACE ENGR BLDG AUBURN UNIVERSITY AL 36849	1

	Copies
ATTN DR MAX PLATZER NAVAL POSTGRADUATE SCHOOL DEPT OF AERONAUTICS & ASTRONAUTICS CODE AA PL MONTEREY CA 93943	1
ATTN MIKE DANGELO MIT LINCOLN LABORATORY 1745 JEFFERSON DAVIS HWY 1100 ARLINGTON VA 22202	1
ATTN RICHARD HAMMER JOHNS HOPKINS APPLIED PHYSICS LAB JOHNS HOPKINS ROAD LAUREL MD 20723-6099	1
ATTN MAURICE TUCKER BATTELLE HUNTSVILLE OPERATIONS 7501 S MEMORIAL PKWY STE 101 HUNTSVILLE AL 35802	1
ATTN STEVE MULLINS SIMULATION AND ENGINEERING CO INC 4935 CENTURY ST NW HUNTSVILLE AL 35816-1901	1
ATTN ROBERT BRAENDLEIU KAISER MARQUARDT 16555 SATICOY ST VAN NUYS CA 91406-1739	1
ATTN LAWRENCE FINK BOEING AIRCRAFT AND MISSILES P O BOX 3707 MC 4A 36 SEATTLE WA 98124-2207	1
ATTN ROY KLINE KLINE ENGINEERING CO INC 27 FREDON GREENDELL RD NEWTON NJ 07860-5213	1
ATTN THOMAS KLAUSE TRW P O BOX 80810 ALBUQUERQUE NM 87198	1

DISTRIBUTION (Continued)

	Copies
ATTN DAN PLATUS THE AEROSPACE CORPORATION P O BOX 92957 LOS ANGELES CA 90009	1
ATTN DR REX CHAMBERLAIN TETRA RESEARCH CORPORATION 2610 SPICEWOOD TR HUNTSVILLE AL 35811-2604	1
ATTN PERRY PETERSEN NORTHROP GRUMMAN CORP DEPT 9B51 MAIL ZONE XA 8900 EAST WASHINGTON BLVD PICO RIVERA CA 90660-3783	1
ATTN DR JAMES HAUSER AERO SPECTRA INC 2850 KENYON CIRCLE P O BOX 3006 BOULDER CO 80307	1
ATTN DARRELL AUSHERMAN TRW SPACE AND DEFENSE ONE SPACE PARK MAIL STATION R1-1062 REDONDO BEACH CA 90278-1071	1
ATTN JAY EBERSOHL ADVATECH PACIFIC INC 2015 PARK AVENUE SUITE 8 REDLANDS CA 92373	1
ATTN EDWARD RAWLINSON SY TECHNOLOGY INC 4900 UNIVERSITY SQUARE SUITE 8 HUNTSVILLE AL 35816	1
ATTN LAYNE COOK UNIVERSAL SPACE LINES 8620 WOLFF CT SUITE 110 WESTMINSTER CO 80030	1
ATTN PAUL WILDE ACTA INC 2790 SKYPARK DR SUITE 310 TORRANCE CA 90505-5345	1

	Copies
ATTN DR MICHAEL HOLDEN CALSPAN UB RESEARCH CENTER P O BOX 400 BUFFALO NY 14225	1
ATTN RICHARD GRABOW SPACE VECTOR CORP 17330 BROOKHURST ST SUITE 150 FOUNTAIN VALLEY CA 92708	1
ATTN BRENT APPLEBY DRAPER LABORATORY 555 TECHNOLOGY SQ MS77 CAMBRIDGE MA 02139	1
ATTN JAMES JONES SPARTA INC 1901 N FORT MYER DR SUITE 600 ARLINGTON VA 22209	1
ATTN SCOTT HOUSER PHOENIX INTEGRATION 1872 PRATT DRIVE SUITE 1835 BLACKSBURG VA 24060	1
ATTN S ROM MURTY TELEDYNE BROWN ENGINEERING MS 200 300 SPARKMAN DRIVE HUNTSVILLE AL 35807	1
ATTN STUART COULTER SVERDRUP TECHNOLOGY 670 2ND ST MS4001 ARNOLD AIR FORCE BASE TULLAHOMA TN 37389-4001	1
ATTN DR RICHARD HOWARD NAVAL POSTGRADUATE SCHOOL DEPT OF AERONAUTICS AND ASTRONAUTICS CODE AA HO NPS MONTEREY CA 93943	1
ATTN J BRENT RUMINE MIT LINCOLN LABORATORY 244 WOOD STREET BUILDING S ROOM 52-327 LEXINGTON MA 02173-9185	1

DISTRIBUTION (Continued)

Copies

NON-DOD ACTIVITIES (EX-CONUS)

ATTN A BOOTH 1
BRITISH AEROSPACE DEFENCE LTD
MILITARY AIRCRAFT DIVISION
WARTON AERODROME WARTON PRESTON
LANCASHIRE PR4 1AX
UNITED KINGDOM

ATTN R CAYZAC 1
GIAT INDUSTRIES
7 ROUTE DE GUERCY
18023 BOURGES CEDEX
FRANCE

ATTN MAJ F DE COCK 1
ECOLE ROYALE MILITAIRE
30 AV DE LA RENAISSANCE
1040 BRUXELLES
BELGIUM

ATTN J EKEROOT 1
BOFORS MISSILES
691 80 KARLSKOGA
SWEDEN

ATTN CH FRANSSON 1
NATIONAL DEFENCE RESEARCH
ESTABLISHMENT
DEPT OF WEAPON SYSTEMS EFFECTS
AND PROTECTION
KARLAVAGEN 106B
172 90 SUNDBYBERG
SWEDEN

ATTN M HARPER BOURNE 1
DEFENCE RESEARCH AGENCY
Q134 BUILDING
RAE FARNBOROUGH
HAMPSHIRE QU14 6TD
UNITED KINGDOM

ATTN A H HASSELROT 1
FFA
P O BOX 11021
161 11 BROMMA
SWEDEN

Copies

ATTN B JONSSON 1
DEFENCE MATERIAL ADMINISTRATION
MISSILE TECHNOLOGY DIVISION
115 88 STOCKHOLM
SWEDEN

ATTN P LEZEAUD 1
DASSAULT AVIATION
78 QUAI MARCEL DASSAULT
92214 SAINT CLOUD
FRANCE

ATTN J LINDHOUT 1
N L R
ANTHONY FOKKERWEG 2
1059 CM AMSTERDAM
THE NETHERLANDS

ATTN A MICKELLIDES 1
GEC MARCONI
DEFENCE SYSTEMS LTD
THE GROVE WARREN LANE
STANMORE MIDDLESEX
UNITED KINGDOM

ATTN K MOELLER 1
BODENSEEWERK
GERAETETECHNIK GMBH
POSTFACH 10 11 55
88641 UBERLINGEN
GERMANY

ATTN RIBADEAU DUMAS 1
MATRA DEFENSE
37 AV LOUIS BREGUET
BP 1
78146 VELIZY VILLACOUBLAY CEDEX
FRANCE

ATTN R ROGERS 1
DEFENCE RESEARCH AGENCY
BLDG 37
TUNNEL SITE
CLAPHAM BEDS MK 41 6AE
UNITED KINGDOM

DISTRIBUTION (Continued)

	Copies
ATTN S SMITH DEFENCE RESEARCH AGENCY Q134 BUILDING RAE FARNBOROUGH HAMPSHIRE QU14 6TD UNITED KINGDOM	1
ATTN J SOWA SAAB MISSILES AB 581 88 LINKOPING SWEDEN	1
ATTN D SPARROW HUNTING ENGINEERING LTD REDDINGS WOOD AMPTHILL BEDFORDSHIRE MK452HD UNITED KINGDOM	1
ATTN P STUDER DEFENCE TECHNOLOGY AND PROCUREMENT AGENCY SYSTEMS ANALYSIS AND INFORMATION SYSTEMS DIVISION PAPIERMUEHLESTRASSE 25 3003 BERNE SWITZERLAND	1
ATTN DR R G LACAU AEROSPATIALE MISSILE DEPT E/ECN CENTRE DES GATINES 91370 VERRIERE LE BUISSON FRANCE	1
ATTN J M CHARBONNIER VON KARMAN INSTITUTE 72 CHAUSSEE DE WATERLOO 1640 RHODE SAINT GENESE BELGIUM	1
ATTN P CHAMPIGNY DIRECTION DE L AERONAUTIQUE ONERA 29 AV DE LA DIVISION LECLERC 92320 CHATILLON SOUS BAGNEUX CEDEX FRANCE	1
ATTN DR P HENNIG DEUTSCHE AEROSPACE (DASA) VAS 414 ABWEHR AND SCHUTZ POSTFACH 801149 8000 MUENCHEN 80 GERMANY	1
ATTN DR S J YOON AGENCY FOR DEFENSE DEVELOPMENT AERODYNAMICS DIVISION (4-3-1) P O BOX 35-4 YUSEONG TAEJON KOREA	1
ATTN PETER CAAP HD FLIGHT SYS DEPT FAA AERONAUTICAL RESEARCH INST OF SWEDEN BOX 11021 BROMMA SWEDEN 16111	1
ATTN DAVE BROWN WEAPON SYSTEMS DIVISION AERONAUTICAL AND MARITIME RESEARCH LABORATORY P O BOX 1500 SALISBURY SOUTH AUSTRALIA 5108	1

INTERNAL

		Copies
B		1
B04		1
B04	(ZIEN)	1
B05	(GRAFF)	1
B05	(HORMAN)	1
B05	(STATON)	1
B10		1
B10	(HSIEH)	1
B51	(ARMISTEAD)	1
B60	(TECHNICAL LIBRARY)	3
C		1
D		1
G		1
G02		1
G04		5
G20		1
G205		1
G23		1
G23	(BIBEL)	1
G23	(COOK)	1

DISTRIBUTION (Continued)

		Copies
G23	(HANGER)	1
G23	(HARDY)	1
G23	(HYMER)	5
G23	(OHLMEYER)	1
G23	(ROWLES)	1
G23	(WEISEL)	1
G24	(ROBINSON)	1
G30		1
G305		1
G32	(DAY)	1
G33	(FRAYSSE)	1
G33	(RINALDI)	1
G50		1
G50	(SOLOMON)	1
G60		1
G70		1
G72		1
G72	(ALEXOPOULOS)	1
G72	(CHEPREN)	1
K		1
K40		1
K44	(ICHNIOWSKI)	1
N		1
T		1
T406		1